Pollution in water and soil from the eruption in Holuhraun, Iceland

Metal concentration analysis

Master's thesis in the Master's Programme of Infrastructure and Environmental Engineering

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Department of Civil and Environmental Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY

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Cover photo: Holuhraun eruption December 13th, 2014. Photo owned and taken by Iurie Belegurschi

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ABSTRACT

A fissure eruption started in Holuhraun, Iceland, on the 29th of August 2014. The volcanic activity gradually decreased and finally came to an end on the 27th of February 2015.

Thousand tonnes of SO_2 were released to the atmosphere per day since the eruption started. Volcanic eruptions are also a natural source for heavy metals which can be toxic in small doses. Heavy metals bioaccumulate in the food chain and are of concern for flora and fauna.

The aim of this thesis project was to assess potential contamination by the eruption in Holuhraun, as well as assess eventual risks. The work focussed on the occurrence of selected metals in surface waters and topsoil collected in Iceland. Samples were collected in February 2015 in the eastern part of Iceland and in the greater capital area for comparison. One drinking water sample was collected at Seyðisfjörður where surface water is used as a drinking water source.

The results for the drinking water samples only indicated leaching from pipes. The soil sample results indicated that there was no pollution in the soil that could be connected to the eruption. Water samples that were collected in the greater capital area had lower heavy metal concentration, indicating possible pollution from the eruption in surface water in the eastern part of Iceland. Correlation analysis implied the same results.

The sampling site, Lagarfljót, had the highest concentration of heavy metals in surface water and the results strongly indicated pollution from the eruption. Comparison with previous analysis from Lagarfljót showed significant increase of heavy metal concentrations.

Keywords: Heavy metals, pollution, concentration, Holuhraun, eruption, SO_2, volcanic gases, drinking water, surface water, soil

Table of contents

Preface

This Master Thesis was carried out from January 2015 to June 2015 as a part of the master's program Infrastructure and Environmental Engineering at the Department of Civil and Environmental Engineering, Chalmers University of Technology.

Firstly we would like to thank our supervisor, Sebastien Rauch, for his guidance during the work of the thesis. We would also like to thank him for showing an interest in our project when we came to him for advice, he then helped us carry out and modify the idea for this thesis.

We would like to thank Mona Pålsson for her guidance in the laboratory and also Jesper Knutsson for helping us with the soil sample preparation.

Thanks to employees at different companies and institutes in Iceland who gave their time to answer our e-mails.

Lastly, we would like to thank our families for their support during our studies over the years. Special thanks to Smári Sveinsson, Bergthora's father, for his help and for being our driver in Iceland when samples were collected.

Göteborg, June 2015

Vala Jonsdottir & Bergthora Smaradottir

Notations

Al	Aluminium
As	Arsenic
Bi	Bismuth
Cd	Cadmium
CO	Carbon monoxide
Co	Cobalt
CO_2	Carbon dioxide
Cr	Chromium
Cu	Copper
Fe	Iron
H_2	Hydrogen
H_2O	Water
H_2S	Hydrogen sulphide
HCl	Hydrogen chloride
He	Helium
HF	Hydrogen fluoride
Hg	Mercury
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
In	Indium
La	Lanthanum
MilliQ	Ultrapure water obtained with MilliQ Water Purification Systems (18.2 MΩ·cm at 25 °C)
Mn	Manganese
Mo	Molybdenum
NHO_3	Nitric acid
Ni	Nickel
Pb	Lead
PE	Polyethylene
Pt	Platinum

Re	Rhenium
Sb	Antimony
Sc	Scandium
Se	Selenium
Sm	Samarium
Sn	Tin
SO_2	Sulphur dioxide
Te	Tellurium
Ti	Titanium
Tl	Thallium
UV	Ultraviolet
V	Vanadium
W	Tungsten
Zn	Zinc

1 Introduction

A fissure eruption started in Holuhraun, Iceland, on the 29th of August 2014 after many weeks of earthquake cycles in Bárðarbunga in Vatnajökull glacier (Keller et al., 2014), see Figure 1. This eruption lasted for only two hours. Two days later, on the 31st of August 2014, another fissure eruption occurred in a nearby crevice. The volcanic activity gradually decreased and finally came to an end on the 27th of February 2015. The eruption lasted for almost 6 months or 181 days. Latest information about the size of the lava field is estimated to be 85 km^2 and the volume approximately 1.4 km^3 (Icelandic Meteorological Office, 2015a). The eruption in Holuhraun is the largest fissure eruption since the Laki eruption in 1783 (Bali et al., 2014).

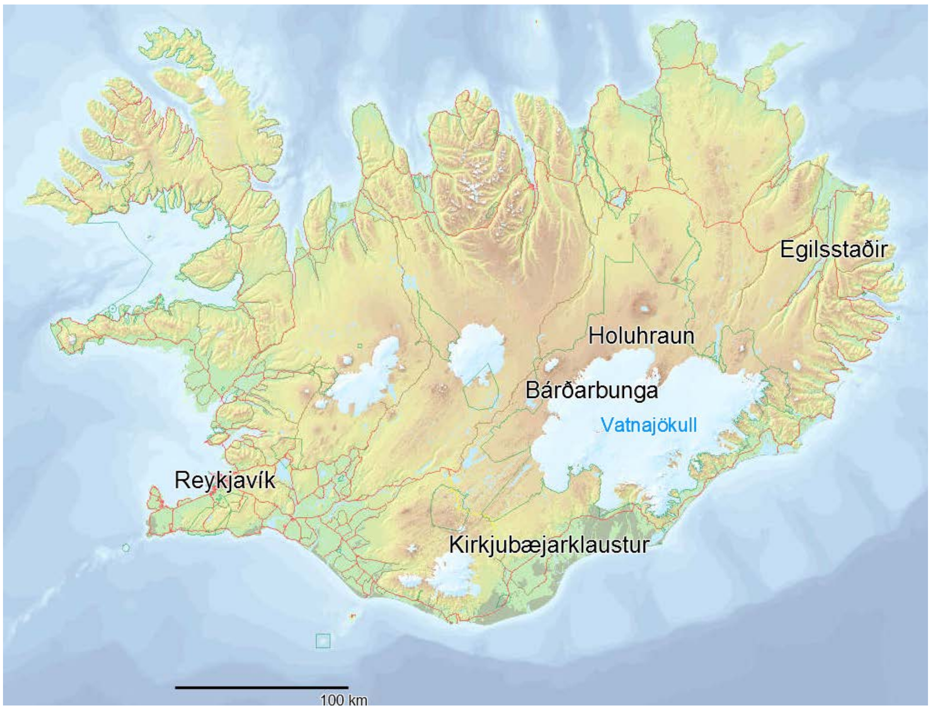

Figure 1 – Map of Iceland and main places discussed regarding the eruption in Holuhraun. Map retrieved and prepared at the website: http://atlas.lmi.is/kortasja/.

Lava and harmful gases, such as sulphur- and carbon compounds, emerge from fissure eruptions (Guðmundsson, 1986). Thousand tonnes of SO_2 were released to the atmosphere per day since the eruption in Holuhraun started (Stefánsson et al., 2014). Therefore the concentration of SO_2 in the atmosphere was carefully monitored all over Iceland. Forecasts for air pollution were also made to make time for appropriate precautions and inhabitants experienced discomfort due to the air pollution all over Iceland.

Volcanic eruptions are a natural source for trace elements such as metals which are volatile at high temperatures (Nriagu, 1989). Although some heavy metals are essential nutrients, they can be toxic in even very small doses and cause damage to all organisms. Heavy metals bioaccumulate in the food chain and they are of concern for flora and fauna (Islam et al., 2007).

For this project, soil and water samples were collected in Iceland in February 2015 to study the impact the eruption in Holuhraun had on metal levels in soil and surface water.

1.1 Aim and objectives

The aim of this thesis project was to assess potential contamination by the eruption in Holuhraun, as well as assess eventual risks. The work focussed on the occurrence of selected metals in surface waters and topsoil collected in the eastern part of Iceland. This was achieved through the following objectives:

- Determine metal concentrations in water and soil from selected locations
- Compare concentrations from different locations to assess volcanic influence
- Compare obtained concentrations with guideline values and regulations

1.2 Summary of work plan

In order to achieve the aim of the project, the following steps were undertaken. Further details are provided in the method section (chapter 4).

- Review literature related to the project.
- Gather available data on water and soil in Iceland from previous chemical analysis.
- Develop a sampling plan
- Collect water and soil samples in Iceland.
- Prepare samples for ICP-MS analysis in laboratory.
- Analyse samples and evaluate the results.

1.3 Limitations

The studied area was narrowed down to several locations along the coast between Egilsstaðir and Kirkjubæjarklaustur. High air pollution was measured at Höfn,[1] a town located between Egilsstaðir and Kirkjubæjarklaustur. This area was therefore found to be the most interesting to study. The area was narrowed down for financial reasons and because of limited time. The number of samples for analysis had to be limited and the cost for gathering samples was high. The sampling sites were chosen close to Highway 1 due to difficult access to more remote sites during winter. For comparison, few samples were collected in lakes close to Reykjavík.

Few previous chemical analysis are available for surface water and soil in Iceland which makes the evaluation of the results more difficult, i.e. not possible to predict if the level of concentration has increased at the sampling sites.

[1] Sigurður H. Magnússon, Plant Ecologist at the Icelandic Institute of Natural History, Áhrif eldgossins á villt dýr og vistkerfi. [Effects of the eruption from Holuhraun on the wildlife ecosystem], seminar regarding the eruption in Holuhraun, March 23rd, 2015

2 Background

Iceland is a volcanic island in the North Atlantic Ocean. The area of Iceland is 103 000 km^2 where approximately 12 000 km^2 are covered with glaciers (Hagstofa Íslands, 2015a). The average yearly temperature for the whole country is around 4.5°C (Hagstofa Íslands, 2015b). Total population in Iceland is approximately 329 000 and more than 60% of the population lives in the greater capital area. The population in the studied area is around 12 500 (Hagstofa Íslands, 2015c).

2.1 Volcanic activity in Iceland

The Mid-Atlantic Ridge lies under Iceland where two of the largest continental plates, the North American plate and the Eurasian plate, move away from each other ca 2 cm per year (Einarsson, 1994), see Figure 2. Iceland is also a so called "hotspot" which is believed to be formed with mantel plume, where turbulent flow is in the mantel. Material which is warmer and has less density finds its way up to the surface and the colder material travels downwards. Over the mantel plume is a localized fusion in the mantel which leads to volcanic activity. This excess volcanic activity results in a thicker earth's crust in Iceland, thicker than what is normal in other places along the Mid-Atlantic Ridge (Vegagerðin, 1997).

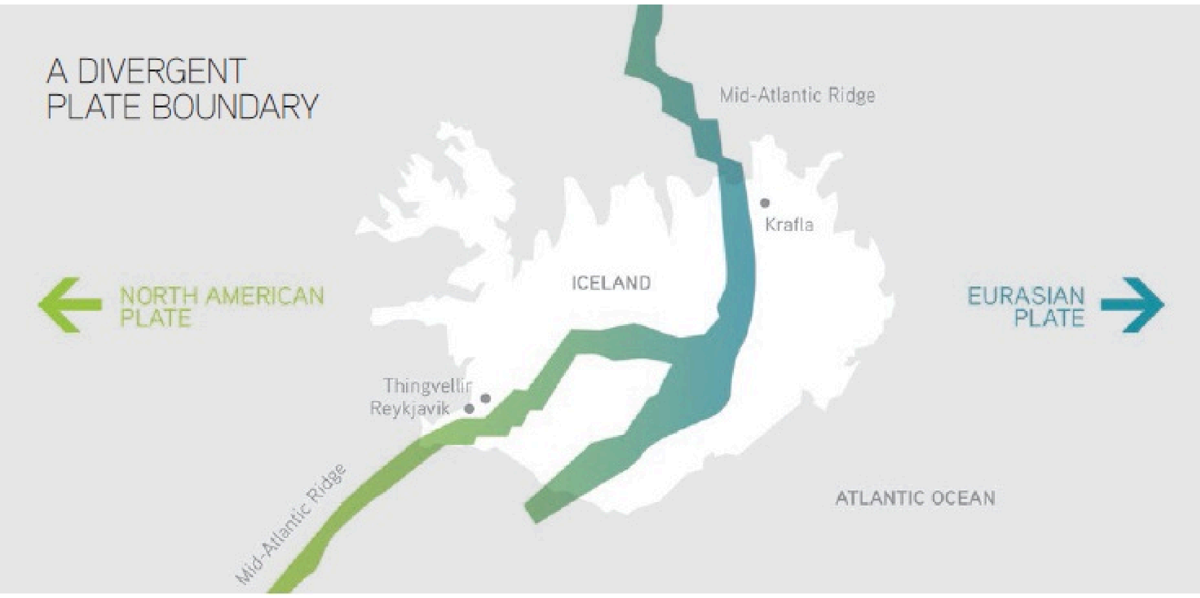

Figure 2 – The Mid-Atlantic Ridge under Iceland. Retrieved from: https://course.bighistoryproject.com/media/khan/KU4.2.4_Lava_img7b.jpg

Combined effects of the continental plates and the mantel plume in Iceland results in high volcanic activity at Vatnajökull glacier area more than in other areas. History shows that volcanic activity can shift in a brief time. The shift can be from active to inactive periods which can be on-going for ten, hundreds or even thousands of years (Vegagerðin, 1997).

Iceland has three volcanic zones; West volcanic zone, East volcanic zone crossing Vatnajökull glacier and a smaller volcanic zone at Snæfellsnes (Einarsson, 1994). Bárðarbunga is one of the main volcanoes located at Vatnajökull glacier (Vegagerðin, 1997).

2.1.1 Recent eruptions

There have been four previous eruptions in the 21st century. Two tephra eruptions in Grímsvötn in west Vatnajökull glacier in November 2004 and in May 2011. Grímsvötn is the most active volcano in Iceland. At least 60 eruptions have occurred in the Grímsvötn volcanic system in the last 800 years. (Jarðvísindastofnun Háskólans, 2012).

On the 20th of March 2010 started a fissure eruption at Fimmvörðuháls, which is close to Eyjafjallajökull glacier, which ended on the 12th of April 2010. Two days later, on the 14th of April a tephra eruption started in Eyjafjallajökull glacier that lasted until the 23rd of May 2010 (Jarðvísindastofnun Háskólans, 2010). The ash plume from the tephra eruption reached over 8 km into the atmosphere and spread over Central Europe, Great Britain and Scandinavia. The spread of the ash caused the largest aviation shut-down in history where more than 100 000 flights were cancelled (Langmann et al., 2011).

2.2 Pollution from Holuhraun

The timeframe of the eruption was convenient for the flora since the eruption was in the beginning of autumn and during winter. The growth period of the flora was almost over and the flora was therefore less vulnerable to the pollution from the eruption. The location of the eruption was also convenient since there is not much flora growth in the nearest area of the eruption.[2]

Precipitation and wind was well above average during winter time in Iceland in the year 2014-2015 with unusually many storms (Icelandic Meterological Office, 2015b). Regarding pollution from the eruption, the weather was fortunate. If the weather had been calmer the polluted snow would have melted all in once in spring. Instead the polluted snow melted in rainstorms possibly causing smaller pollution peaks in spring.[3]

2.2.1 Air pollution

Unlike the eruption in Eyjafjallajökull glacier the eruption in Holuhraun only emitted volcanic gasses and no tephra. The main volcanic gases from the eruption in Holuhraun were H_2O, CO_2 and SO_2. Other gases in smaller amounts were H_2S, H_2, CO, HCl, HF and He. The main concern for human health was SO_2 which can cause irritation in eyes, throat, and respiratory organs. In large dozes SO_2 can cause respiratory problems (Directorate of Health, 2014). Large amount of SO_2 in the atmosphere can result in acid rain which can affect soil and vegetation as well as infrastructure (Stefánsson et al., 2014).

The amount of SO_2 emission was ranging from 35 000 to 100 000 tonnes per day during the eruption (Stefánsson et al., 2014). That is more than the total SO_2 emission in Iceland caused

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[2] Sigurður H. Magnússon, Plant Ecologist at the Icelandic Institute of Natural History, Áhrif eldgossins á villt dýr og vistkerfi. [Effects of the eruption from Holuhraun on the wildlife ecosystem], seminar regarding the eruption in Holuhraun, March 23rd, 2015

[3] Eydís Salóme Eiríksdóttir, PhD student at University of Iceland, Mengun yfirborðsvatns. [Surface water pollution], seminar regarding the eruption in Holuhraun, March 23rd, 2015

by human activity, including geothermal heat, which is now reaching over 80 000 tonnes per year (Hagstofa Íslands, 2015d).

More monitors were installed especially to monitor the concentration level of SO_2 in different places around Iceland. The concentration measured in habituated areas depends on how much SO_2 is emitted in to the atmosphere; how high the plume rises, wind direction and wind strength.[4] Inhabitants can experience discomfort when the concentration of SO_2 exceeds 350 µg/m³ for more than 10 minutes. The health limit for the hourly value of SO_2 pollution is 350 µg/m³ (The Environment Agency of Iceland, 2015). Mice were found dead around Holuhraun and near Höfn and small birds were found dead in Hrafnkelsdalur valley, located in between Holuhraun and Lagarfljót, after high concentration of SO_2 had been measured that day.[5]

Table 1 shows reviewed data on SO_2 concentration from four locations, received from the Environmental Agency of Iceland. Reykjahlíð is located north of Holuhraun and Reyðarfjörður is located south of Egilsstaðir, ca 30 km away. Graphs and further data can be found in Appendix I – Data on SO_2 concentration.

Table 1 – Hourly concentration of SO_2 from 31st of August 2014 – 1st of February 2015.

Location	Max SO_2 µg/m³	Average SO_2 µg/m³	Hours >350 µg/m³	Days >350 µg/m³
Reykjahlíð, Elementary school	1698	30	84	3.50
Reyðarfjörður, Hjallaleyra	1509	32	52	2.17
Höfn*	3050	58	119	4.96
Reykjavík, Grensásvegur**	823	30	59	2.46

* 28th of October 2014 – 1st of February 2015
** 31st of August 2014 – 21st of January 2015

2.3 Metals from volcanic eruptions

Natural sources of trace metals are volcanic eruptions, wild forest fires, wind-borne soil particles and sea salt spray. Metals from volcanic eruptions are among others: As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, V and Zn (Nriagu, 1989).

2.3.1 Concentrations in volcanic plume

Trace metals are known to be emitted with gas from volcanic eruptions. However it is has been difficult to assess because of very high temperature (Gauthier et al., 2015). Trace elements such as K, Na, Fe, Cu, Zn, As, Rb, Mo, Cd, Sn, Cs and Pb are considered to have concentrations ranging from 1 ppb to 15 ppm in high temperature volcanic gases (Africano et al., 2002). An opportunity came along for scientists to analyse plume from the eruption in Holuhraun on October 2nd, 2014. Analysis of diluted plume showed that the air was enriched

[4] Þorsteinn Jóhannsson, Specialist in air quality at The Environment Agency of Iceland, news interview, September 11th, 2014.

[5] Sigurður H. Magnússon, Plant Ecologist at the Icelandic Institute of Natural History, Áhrif eldgossins á villt dýr og vistkerfi. [Effects of the eruption from Holuhraun on the wildlife ecosystem], seminar regarding the eruption in Holuhraun, March 23rd, 2015

of trace metals (Cu, Zn, As, Se, Cd, In, Sn, Sb, Te, Tl, Pb, Bi, Mo, W and Re) compared to the usual atmosphere in Iceland. At the end of 2014 more than 25 tons of Cd had been emitted from the eruption, showing that the eruption is a major pollutant to the atmosphere and the environment (Gauthier et al., 2015).

2.3.2 Concentrations in glacial water

In Iceland, volcanic dust is the main source of heavy metals in glacial water. Studies from 2005 examined samples from Sólheimajökull glacier, the most southern glacier in Iceland, which is a part of Mýrdalsjökull glacier, and Fláajökull glacier which is a part of Vatnajökull glacier in the south west. The results of the study gave the average concentrations of Fe, Zn, Mn and Pb which can be found in Table 2 (Józwiak & Józwiak, 2007).

Table 2 – Average concentrations of metals in glacial water from Sólheimajökull glacier and Fláajökull glacier.

	[μg/dm^3] (ppb)
Fe	9.05
Zn	8.60
Mn	0.43
Pb	0.14

2.3.3 Concentrations in snow

Research on snow that was analysed during the Hekla eruption in Iceland in 1991 showed high concentrations of metals. The results showed high concentrations of Ti, Mn and Fe, higher than 100 ppb. Concentrations of Cu and Zn were between 10 and 100 ppb and concentrations between 1 to 10 ppb of Sc, V, Cr, Co, As, Se, Sn, La and Sm. The research showed that volcanic eruptions can cause heavy metal pollution and could be dangerous to flora and fauna (Ragnarsdóttir et al., 1994).

Another study on polar ice layers showed that volcanic eruptions can cause high concentrations of Cd, Hg, As, Cr, Cu, Ni, Pb and Sb (Nriagu, 1989).

2.3.4 Concentrations in soil

The average values of trace elements in soil worldwide can be found in Table 3. These values are from a database that gives the average concentrations of trace elements in uncontaminated soil (Kabata-Pendias, 2011). Table 3 only shows elements that are relevant to this project. Concentrations of trace elements are dependent on type of soil and geographic region (Kabata-Pendias, 2011).

Table 3 – Average values of trace elements in world soil (Kabata-Pendias, 2011).

	World soil average [mg/kg]
Cd	0.41
Cr	59.5
Co	11.3
Cu	38.9
Mn	488
Ni	29
Ti	7038
V	129
Zn	70

La Réunion is a small island in the Indian Ocean which belongs to France. It is formed by two volcanoes, of which one of them is still active. Soil samples were collected on 39 sites, which were analysed with ICP-OES to determine heavy metal concentration (Dælsch et al., 2006).

Table 4 shows the results from the chemical analysis for six elements.

Table 4 – Concentration of heavy metals in soil at La Réunion (Dælsch, et al., 2006).

	Cd [mg/kg]	Cr [mg/kg]	Cu [mg/kg]	Hg [mg/kg]	Ni [mg/kg]	Zn [mg/kg]
Minimum	0.02	35	6.5	0.03	15	57
Mean	0.19	300	58	0.19	206	162
Maximum	0.76	1108	164	0.81	1038	398

The values in Table 4 are higher than the world average values in Table 3. High concentration of Cd was directly related to agricultural practices and high concentration of Hg was connected to the volcanic activity on the island. The high concentrations for the rest of the elements are due to the fact that the samples were collected from volcanic soil from the two volcanoes (Dælsch et al., 2006).

Study of characterization of heavy metal in contaminated volcanic soil was done in Solofrana river valley in south of Italy. The study estimated the concentration of heavy metals in soil after a flooding. Samples were taken from five different sampling sites where only one was in no relation to the flooding of the river and not considered polluted. Chemical analysis for that sampling site can be found in Table 5.

Table 5 – Concentration of heavy metals in Solofrana river valley (Adamo, et al., 2003).

	Fe [mg/kg]	Cr [mg/kg]	Cu [mg/kg]	Mn [mg/kg]	Ni [mg/kg]	Pb [mg/kg]	Zn [mg/kg]
Concentration of heavy metals	60 300	45	110	689	41	63	82

2.4 Tolerance against SO_2 pollution

When SO_2 comes in contact with water it produces sulphuric acid and the water becomes acidic.[6] Acid rain lowers the pH-value in surface water and toxic metals become more soluble and bioavailable when pH-value is lowered. (Weiner, 2013). Aluminium is known to have a negative effect on the ecosystem in water in relation to this. Acidic episodes and related metals can be harmful to the ecosystem and the effects depend on the duration and the concentration of the episode.[7]

Alkalinity and the pH-value differ in surface water. When the pH-value and the alkalinity are naturally high, the water has more tolerance against SO_2 pollution. With higher alkalinity, the more acid the water can receive without it affecting the chemical quality.[8]

In areas with young bedrock, close to the volcanic zone, the pH-value and alkalinity is high in the water ecosystem. Therefore the water quality is less sensitive to changes and the pH-value will not decrease as much. The most vulnerable water ecosystems are in old bedrock where there is not much soil and vegetation. Water's ecosystem, close to the eruption site, should therefore be less sensitive. However the sampling sites are located on old bedrock where surface water tends to have lower alkalinity.[9]

Vatnajökull glacier is located on the volcanic zone and glacial water has high alkalinity. Scientist tested polluted snow from the eruption site and mixed with two different rivers to lower the concentration of aluminium to make it less harmful to salmonids and juveniles. The glacial river Jökulsá á Fjöllum mixed with the polluted snow had to be diluted 5 times. Fjarðará river, which can be consider to have low alkalinity, had to be diluted 35 times to reach the desired aluminium concentration.[10]

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[6] Halla Margrét Jóhannesdóttir, scientist at Institute of Freshwater Fisheries, Áhrif eldgossins á lífríki í ám og vötnum. [Effect of the eruption on ecosystem in freshwater], seminar regarding the eruption in Holuhraun, March 23rd, 2015

[7], Halla Margrét Jóhannesdóttir, scientist at Institute of Freshwater Fisheries, Áhrif eldgossins á lífríki í ám og vötnum. [Effect of the eruption on ecosystem in freshwater], seminar regarding the eruption in Holuhraun, March 23rd, 2015

[8] Eydís Salóme Eiríksdóttir, PhD student at University of Iceland, Mengun yfirborðsvatns. [Surface water pollution], seminar regarding the eruption in Holuhraun, March 23rd, 2015

[9] Halla Margrét Jóhannesdóttir, scientist at Institute of Freshwater Fisheries, Áhrif eldgossins á lífríki í ám og vötnum. [Effect of the eruption on ecosystem in freshwater], seminar regarding the eruption in Holuhraun, March 23rd, 2015

[10] Eydís Salóme Eiríksdóttir, PhD student at University of Iceland, Mengun yfirborðsvatns. [Surface water pollution], seminar regarding the eruption in Holuhraun, March 23rd, 2015

3 Icelandic regulations and guidelines

Chapters 3.1 and 3.2 discuss the Icelandic regulations on water quality for surface water and drinking water. There are no existing Icelandic regulations regarding heavy metal pollution in soil. However, guidelines on pollution in soil are discussed in chapter 3.3.

3.1 Surface water regulations

The Icelandic regulations regarding water aim to prevent and minimize pollution in water and its surroundings. Regulation no. 796/1999 describes i.a. the environmental standards for metals in surface water, see Table 6. The standards can be translated to the following (Umhverfisráðuneytið, 1999):

Standard I: No risk or very small possibility of impact
Standard II: Small possibility of impact
Standard III: Possibility of impact on fragile ecosystem
Standard IV: Possibility of impact
Standard V: Unsatisfactory condition of water for ecosystem

Table 6 – Environmental standards for metals in surface water.

Environmental standards for metal concentration [ppb]						
		I	**II**	**III**	**IV**	**V**
Copper	Cu	0.5	0.5-3	3-9	9-45	>45
Zinc	Zn	5	5-20	20-60	60-300	>300
Cadmium	Cd	0.01	0.01-0.1	0.1-0.3	0.3-1.5	>1.5
Lead	Pb	0.2	0.2-1	1-3	3-15	>15
Chromium	Cr	0.3	0.3-5	5-15	15-75	>75
Nickel	Ni	0.7	0.7-15	15-45	45-225	>225

3.2 Drinking water regulations

Iceland is very rich of clear and unpolluted groundwater and almost all drinking water in Iceland, more than 95%, is untreated groundwater. Only few places with small population use surface water for a drinking water source. In most cases the surface water is treated with ultraviolet light before distribution (Jónsson, 2003).

Table 7 shows the maximum concentration for metals in drinking water that were extracted from the Icelandic regulation no. 536/2001 (Umhverfisráðuneytið, 2001).

Table 7 – Maximum concentration of metals in drinking water

		Maximum concentration [ppb]
Aluminium	Al	200
Lead	Pb	10
Iron	Fe	200
Cadmium	Cd	5.0
Copper	Cu	2000
Chromium	Cr	50
Manganese	Mn	50
Nickel	Ni	20

3.3 Soil guidelines

As previously mentioned, no Icelandic regulations regarding heavy metal concentrations in soil exist. A guideline and a draft for such regulations however exist and were received from the Environmental Agency of Iceland (The Environmental Agency of Iceland, 1998).

The guideline is for soil and marine sediment and is based on Dutch regulations. Few changes were made since the Icelandic background values are higher for Cr, Cu, Ni and Zn. Compared to Europe, Icelandic bedrock has higher concentrations of Cr, Cu, Ni and V, however, less of As, Cd, Hg and Pb. Icelandic soil is also rich of wind-borne volcanic gas particles (The Environmental Agency of Iceland, 1998).

Table 8 shows the guideline for upper and lower threshold of metal concentration in Icelandic soil. The values inside the brackets are the values of the Dutch regulations (The Environmental Agency of Iceland, 1998).

Table 8 – Guidelines for metal concentrations in Icelandic soil.

	Background values [mg/kg]	Lower threshold [mg/kg]	Upper threshold [mg/kg]
Cd	0.1-0.3	0.8	12
Cr	300-400	300-400 (100)	380
Cu	100-200	100-200 (36)	190
Ni	10-200	10-200 (35)	210
Pb	1-10	85	530
Zn	50-200	50-200 (140)	720

Each case has to be assessed and evaluated if action needs to be taken when metal concentration is between the lower and the upper threshold or above the upper threshold. The ratio of organic material and clay affect the threshold. Pollutants have less impact when the ratio is high and therefore the threshold is higher (The Environmental Agency of Iceland, 1998).

4 Method

4.1 Sampling

Water samples were collected in small PE bottles and soil samples were collected in ziplock PE bags. Nitric acid (65% NHO_3, puriss) was added to the surface and drinking water samples soon after collection, approximately 0.3% of the volume. Small plastic syringes were used to add the acid to the samples. Caution was taken to make sure that the acid did not come in contact with the rubber in the syringes. The scale on the PE bottles and the syringes were not accurate, therefore the accuracy for the added acid was estimated to be ± 0.1%.

After collection both water and soil samples were stored in a cool and dark place until they were shipped to Sweden. After arriving in Sweden they were stored in a refrigerator.

4.1.1 Surface water and soil samples

Three water samples were collected in each site along with three soil samples from the surroundings.

Close to Reykjavík, samples were collected in three lakes; Hvaleyrarvatn, Vífilsstaðavatn and Elliða-vatn, on the 9^{th} of February 2015, see Figure 4 for locations.

In the East, from Egilsstaðir to Kirkjubæjar-klaustur, samples were collected at; Langavatn, Urriðavatn, Lagarfljót, Nýjalón on the 10^{th} of February 2015. Furthermore at Óslandstjörn, Þveit, Smyrlabjargarlón, Hoffell and Jökulsárlón on the 11^{th} of February 2015. As previously mentioned the winter in 2014-2015 in Iceland was harsh with many storms and therefore it was very fortunate that the weather was good during sample collection as can be seen in Figure 3. For locations of sampling sites see Figure 5 and Figure 6 and for description of the sites, see Table 9.

Figure 3 – Collecting water samples at Jökulsárlón. (Photo taken by Vala Jónsdóttir, 2015)

Table 9 – Description of sampling sites.

Site	Type	Description
Hvaleyrarvatn	Lake	South of the municipality of Hafnarfjörður.
Vífilsstaðavatn	Lake	Situated in the municipality of Garðabær.
Elliðavatn	Lake/Storage reservoir	Situated in Reykjavík. Storage reservoir for the hydroelectric power plant in the Elliðaárdalur valley.
Langavatn	Lake	5 km north-west of the town Egilsstaðir
Urriðavatn	Lake	5 km north of the town Egilsstaðir
Lagarfljót	Lake/Glacial river	Glacial river flowing from Eyjabakkajökull glacier (Vatnajökull glacier). Forms the third largest natural lake in Iceland in the valley Fljótsdalur (Rist, 1990).
Nýjalón	Lake/Pond	South of the town Djúpivogur
Óslandstjörn	Pond	South of the town Höfn
Þveit	Lake	10 km west of the town Höfn
Hoffell	Glacier lagoon	Glacier lagoon at the edge of Hoffellsjökull glacier which is a part of Vatnajökull glacier.
Smyrlabjargarlón	Lake/Storage reservoir	Storage reservoir for the hydroelectric power plant Smyrlabjargarvirkjun.
Jökulsárlón	Glacier lagoon	Glacier lagoon at the edge of Breiðamerkurjökull glacier which is a part of Vatnajökull glacier.

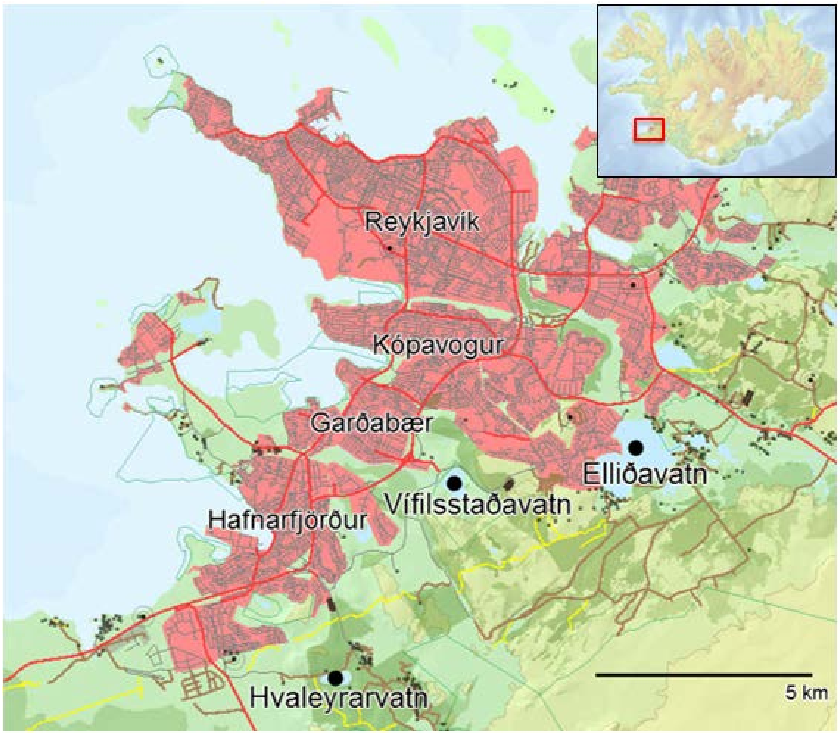

Figure 4 – Location of lakes in the greater capital area. Map retrieved and prepared at the website: http://atlas.lmi.is/kortasja/.

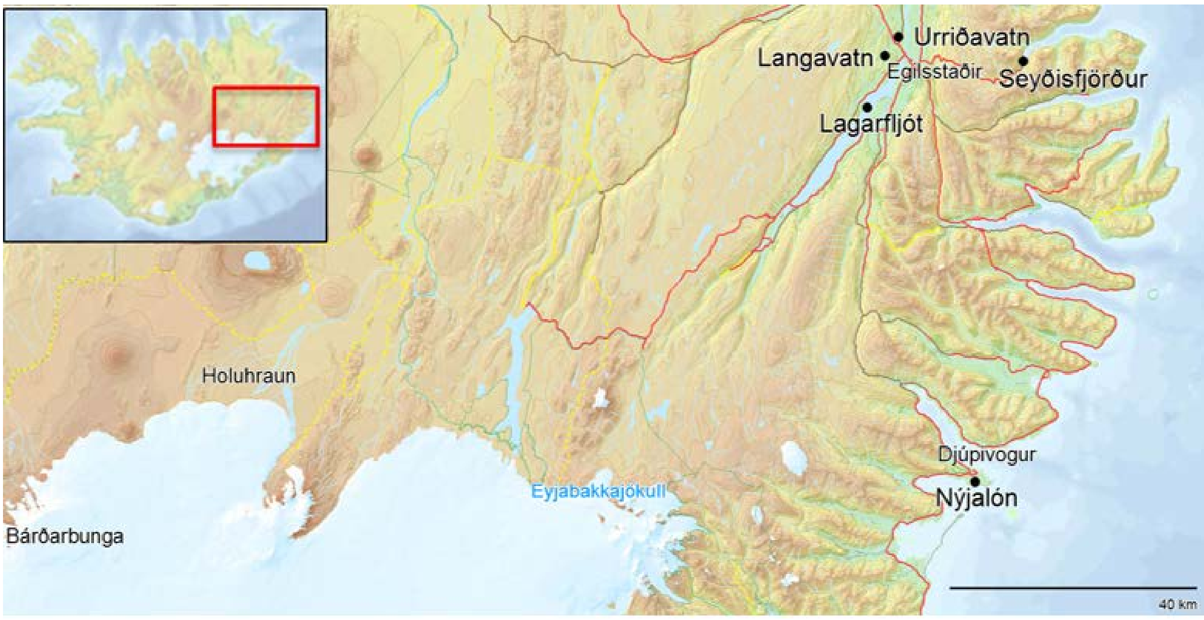

Figure 5 – Location of sample sites north of Holuhraun. Map retrieved and prepared at the website: http://atlas.lmi.is/kortasja/.

Figure 6 – Location of sample sites south of Holuhraun. Map retrieved and prepared at the website: http://atlas.lmi.is/kortasja/.

At sites where lakes were frozen, a hammer was used to crack the ice in order to collect water samples. The PE bottles were slowly lowered upstream in the water to create minimum turbulence when collection took place.

Since the soil was frozen in most of the sites, at the time when soil samples were collected, a hammer and a stainless steel chisel were used to loosen the soil, as can be seen in Figure 7. In sites where the soil was loose or not frozen, a stainless steel spatula was used to scoop the soil into the ziplock PE bags. The soil samples were all collected from the surface, at 0-8 cm depth.

All samples were collected as far away from main roads as possible to minimize potential traffic related pollution.

Figure 7 – Collecting soil samples at Smyrlabjargarlón. (Photo taken by Bergthora Smaradottir, 2015)

4.1.2 Drinking water samples

Drinking water samples were collected where surface water is the main drinking water source. On the studied area only one town, Seyðisfjörður, was found to be using surface water as drinking water source where the water is treated with UV light according to the data in Appendix II – Drinking water data for Seyðisfjörður. The data was received from the Department of Environment in the East. Three samples were collected from a tap after the water had been running for a few minutes until steady temperature was reached and to minimize the risk of water contamination from the pipes.

4.2 Laboratory work

All samples were prepared and analysed in the Environmental Chemistry Laboratory at the Department of Civil and Environmental Engineering, Chalmers University of Technology. Samples were prepared using two calibrated pipettes, one pipette for 1000-5000 µl with accuracy of ± 40 µl and one for 20-200 µl with accuracy of ± 1.6 µl.

4.2.1 Surface water and drinking water samples

Samples were prepared for ICP-MS analysis by pipetting 10 ml of water samples into 12 ml plastic tubes. Samples were taken out of the refrigerator to reach room temperature before pipetting.

Six additional control samples were prepared, where 9.9 ml of MilliQ water was pipetted into sampling glasses along with 0.1 ml of nitric acid. Three control samples contained suprapure 65% nitric acid (MQ S) and three contained puriss nitric acid (MQ P). The control samples were mixed by turning them upside down five times. The control samples were prepared to check for metal concentration in the acid that could affect the results of the collected samples.

The collected samples along with the six control samples were analysed by ICP-MS. The samples were given the numbering found in Table 10.

Table 10 – Numbering of the water samples.

Sample number	Location
1 - 3	Hvaleyrarvatn
4 - 6	Vífilsstaðavatn
7 - 9	Elliðavatn
10 - 12	Langavatn
13 - 15	Urriðavatn
16 - 18	Lagarfljót
19 - 21	Nýjalón
22 - 24	Óslandstjörn
25 - 27	Þveit
28 - 30	Hoffell
31 - 33	Smyrlabjargarlón
34 - 36	Jökulsárlón
37 - 39	Seyðisfjörður
40 - 42	MQ S
43 - 45	MQ P

4.2.2 Soil samples

Soil samples were moved from the ziplock PE bags to glass containers and dried overnight at 105°C. After drying, the samples were crushed and stored in a desiccator. Large stones were hand picked out from the samples. Color, maximum grain size, and other necessary information were noted for each sample.

Samples were hand sieved using a brass sieve. Each sample was shaken for one and a half minute to separate grain sizes less than 0.5 mm. About 250 mg of the sieved samples were weighed and put in a Teflon vessel followed with 2 ml of HCl and 6 ml of HNO_3 (*aqua regia*). The samples were then digested in a closed vessels microwave digestion system (CEM Mars5). The samples were digested at 190°C for 30 minutes at 200 psi and let cool down for 15 minutes, or until the temperature reached around 50°C.

The samples were digested in the microwave in three rounds since the microwave could only digest 14 samples at a time. Each round contained one sample from each sampling site. This was done in case if something would go wrong with the digestion.

After digestion the samples were transferred to 12 ml plastic tubes. Three samples turned out to be completely dried up. However, since the dried samples were so few and all from different sampling sites it was not considered necessary to digest these samples again.

Before the samples were analysed by ICP-MS they were diluted 100 times with MilliQ water. The samples were then stored in a refrigerator until analysis. The prepared soil samples were given the numbering found in Table 11. Samples number 6, 7 and 21 were dried up during microwave digestion.

Table 11 - Numbering of the soil samples.

Sample number	Location
1 - 3	Hvaleyrarvatn
4 - 6	Vífilsstaðavatn
7 - 9	Elliðavatn
10 - 12	Langavatn
13 - 15	Urriðavatn
16 - 18	Lagarfljót
19 - 21	Nýjalón
22 - 24	Óslandstjörn
25 - 27	Þveit
28 - 30	Hoffell
31 - 33	Smyrlabjargarlón
34 - 36	Jökulsárlón

4.2.2.1 Data analysis

In order to find the concentration in the unit mg/kg Equation 1 was used.

$$Results\ \left[\frac{mg}{kg}\right] = \frac{Results\ \left[\frac{mg}{ml}\right] \cdot Dilution\ factor \cdot Volume\ of\ acid\ [ml]}{Sample\ weight\ [kg]}$$

(Equation 1)

Where the dilution factor is 100 and the volume of acid is 8 ml (6 ml NHO_3 + 2 ml HCl). The sample weight is approximately 250 mg. Results in ppb had to be converted to mg/ml.

5 Results

5.1 Surface water and drinking water samples

Heavy metals that were analysed by ICP-MS for the water samples are Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Sb, Pt and Pb. The average concentrations of these elements can be found in Table 12, for the three samples taken at each sampling site. Results for each sample by numbering can be found in Appendix III – ICP-MS results for water samples.

Table 12 – Average concentration in water samples from ICP-MS analysis.

	Al	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**
	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
Hvaleyrarvatn	65	8.4	0.22	0.06	31	66	0.92
Vífilsstaðavatn	21	19.3	2.8	0.49	6.5	117	0.83
Elliðavatn	38	13.1	2.6	0.24	23	343	1.11
Langavatn	128	38	0.89	0.11	90	2 282	1.05
Urriðavatn	19.9	15.7	0.25	0.08	51	368	1.04
Lagarfljót	6 782	1 182	25	4.7	152	11 152	3.6
Nýjalón	497	61	3.3	0.55	85	3 205	1.11
Óslandstjörn	54	10.0	0.77	0.16	7.8	921	0.85
Þveit	571	83	2.8	0.44	125	1 363	1.25
Hoffell	1 322	272	24	1.18	35	2 268	1.68
Smyrlabjargarlón	314	41	1.89	0.22	43	580	1.05
Jökulsárlón	132	438	8.9	0.29	16.7	143	0.90
Seyðisfjörður	165	9.0	0.46	0.02	10.5	125	0.95
	Ni	**Cu**	**Zn**	**Cd**	**Sb**	**Pt**	**Pb**
	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppt]	[ppb]
Hvaleyrarvatn	0.30	0.66	2.7	0.01	0.00	0.36	0.07
Vífilsstaðavatn	0.24	0.50	1.72	0.01	0.00	1.08	0.05
Elliðavatn	0.67	1.36	39	0.02	0.03	0.49	0.10
Langavatn	0.50	0.65	4.7	0.01	0.00	1.16	0.05
Urriðavatn	0.33	0.59	4.5	0.01	0.00	0.71	0.04
Lagarfljót	4.3	16.8	13.0	0.02	0.00	0.78	0.14
Nýjalón	1.32	2.9	35	0.10	0.00	0.25	0.26
Óslandstjörn	0.84	1.10	8.7	0.01	0.03	0.00	0.11
Þveit	0.86	1.46	4.4	0.02	0.00	0.40	0.10
Hoffell	1.49	4.8	5.8	0.01	0.02	1.41	0.09
Smyrlabjargarlón	0.43	1.43	3.3	0.01	0.00	0.34	0.07
Jökulsárlón	2.1	28	2.5	0.03	0.21	0.15	0.04
Seyðisfjörður	0.47	3.8	1 656	0.03	0.00	0.39	0.28

Figure 8, Figure 9 and Figure 10 show a schematic view of the results in Table 12, excluding the results for Seyðisfjörður that are discussed later in chapter 6.2. Figure 8 shows that samples collected in the greater capital area have lower Fe, Ti and Al concentrations. This is the first indication that the water in the eastern part of Iceland is affected by the eruption in Holuhraun.

The glacier lagoons, Jökulsárlón and Hoffell, and the glacial river Lagarfljót have the highest concentrations of Ti, Cu and V, according to Figure 8 and Figure 9. Concentrations of Mn and Zn do not seem to follow any specific pattern regarding location. Jökulsárlón, Hoffell and Lagarfljót have the highest concentration of Ni. Concentrations of Cr, Ni and Co at Lagarfljót are significantly higher than at other sampling sites, see Figure 10.

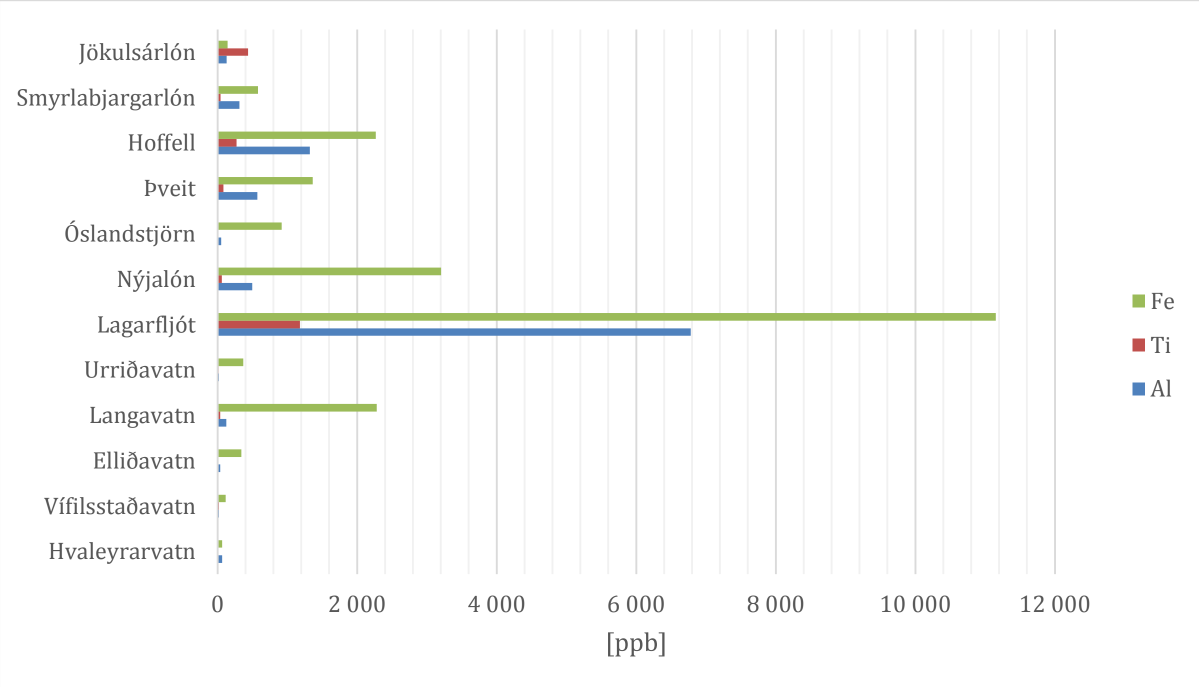

Figure 8 – Schematic view of water results for Fe, Ti and Al.

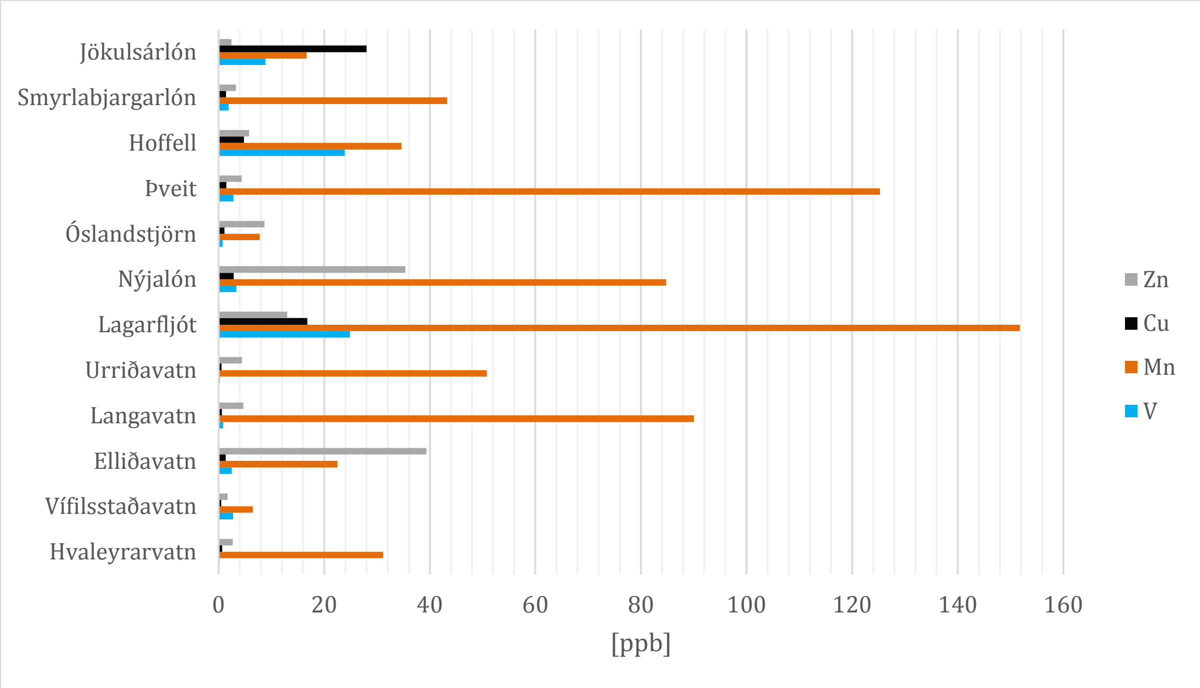

Figure 9 – Schematic view of water results for Zn, Cu, Mn and V.

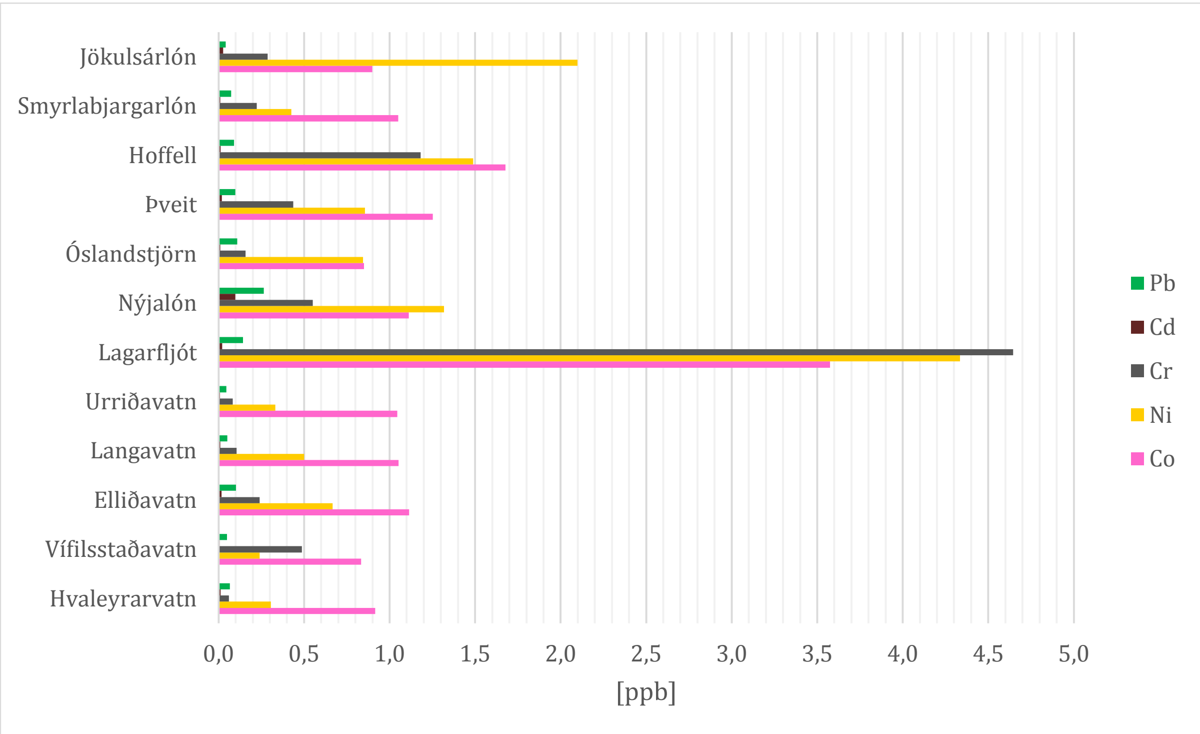

Figure 10 – Schematic view of water results for Pb, Cd, Cr, Ni and Co.

5.1.1 Correlation analysis

Correlation analysis was done for the metals that were analysed in water and the results are shown in Table 13. The correlation values were obtained in Microsoft Excel using the function correl. The values range between -1 to 1 where -1 is perfect negative correlation and 1 is perfect positive correlation. Values less than 1 have two decimals except for negative values that only have one decimal. One group of metals can be distinguished based on correlations, i.e. Al, Ti, Fe, Co and Ni, whereas the other metals do not show any correlation, except for Pb and Cd.

Table 13 – Correlation of metals for water results

	Al	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Cd**	**Sb**	**Pt**	**Pb**
Al	1													
Ti	0.94	1												
V	0.78	0.82	1											
Cr	0.99	0.94	0.81	1										
Mn	0.67	0.55	0.35	0.63	1									
Fe	0.96	0.88	0.71	0.96	0.76	1								
Co	0.99	0.92	0.81	0.98	0.69	0.96	1							
Ni	0.90	0.97	0.81	0.90	0.55	0.87	0.88	1						
Cu	0.43	0.71	0.52	0.44	0.11	0.35	0.39	0.73	1					
Zn	0.06	0.0	0.0	0.08	0.10	0.17	0.09	0.12	-0.1	1				
Cd	0.01	0.02	0.0	0.03	0.24	0.18	0.0	0.20	0.13	0.64	1			
Sb	-0.1	0.20	0.12	-0.1	-0.4	-0.2	-0.2	0.26	0.82	-0.1	0.07	1		
Pt	0.21	0.14	0.45	0.25	0.13	0.21	0.28	0.03	-0.2	-0.2	-0.3	-0.3	1	
Pb	0.29	0.16	0.17	0.30	0.40	0.45	0.29	0.34	-0.1	0.71	0.85	-0.3	-0.3	1

5.2 Soil samples

Heavy metals analysed in the soil samples are Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Sb, Pb and Sn. Table 14 shows the average concentration in the soil samples for these elements. Results below 20 have one decimal and results below 2 have two decimals. Results for each sample by numbering can be found in Appendix IV – ICP-MS results for soil samples. Only two of the three sample results for Smyrlabjargarlón were used for the average value, since the third sample result was considered to be an outlier and could not be explained.

The chemical analysis in ICP-MS was run in two separate rounds for the soil samples. Cr, Ni, Cu, Zn, Cd, and Pb were analysed in the first round and Al, Ti, V, Mn, Fe, Co, Sn, Sb were analysed in the second round. Al, Ti, V, Mn, Fe, Co, Sn, Sb concentrations are missing for sample 1 because of a software problem in the second round.

Table 14 – Average concentration in soil samples from ICP-MS analysis.

	Al	Ti	V	Cr	Mn	Fe	Co
	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]
Hvaleyrarvatn	89 390	3 946	213	239	2 484	182 746	143
Vífilsstaðavatn	47 796	2 990	124	34	929	66 810	29
Elliðavatn	78 298	1 907	365	79	938	85 641	45
Langavatn	66 578	2 646	190	58	2 857	147 782	53
Urriðavatn	41 594	2 805	167	26	5 334	118 956	85
Lagarfljót	44 708	3 939	242	27	769	79 931	31
Nýjalón	41 685	3 195	121	21	868	57 539	30
Óslandstjörn	64 769	5 340	285	41	1 617	104 445	37
Þveit	54 634	4 297	202	30	993	74 716	29
Hoffell	42 279	5 190	202	20	877	68 239	23
Smyrlabjargar-lón	49 784	4 994	197	29	871	74 533	28
Jökulsárlón	33 060	4 846	130	27	632	49 468	19
	Ni	**Cu**	**Zn**	**Cd**	**Sb**	**Pb**	**Sn**
	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]	[mg/kg]
Hvaleyrarvatn	725	313	244	0.23	0.06	6.5	1.79
Vífilsstaðavatn	59	59	61	0.18	0.05	7.4	2.5
Elliðavatn	95	135	133	0.26	0.01	6.3	1.60
Langavatn	68	158	112	0.24	0.04	4.5	1.21
Urriðavatn	31	86	73	0.16	0.02	2.2	2.2
Lagarfljót	43	102	93	0.05	0.02	1.45	3.0
Nýjalón	50	55	50	0.18	0.01	3.3	1.67
Óslandstjörn	43	118	168	0.29	0.02	24	3.8
Þveit	30	110	117	0.21	0.01	4.6	2.4
Hoffell	27	102	89	0.11	0.02	2.2	2.1
Smyrlabjargar-lón	28	87	57	0.10	0.02	3.8	1.95
Jökulsárlón	27	60	45	0.05	0.02	1.32	2.3

As previously mentioned only two sample results were used for Smyrlabjargarlón. The third sample results are approximately 10 times higher than the other two, and in no relation to the other two samples. No obvious reasons were found for the high concentration and therefore it was decided to exclude that sample from the average value. A likely reason for the high concentration could be that a fraction of the sample contained very high concentrations of heavy metals. No obvious difference could be seen between the three samples, i.e. the colour, grain size and texture was similar. It would have been preferable to analyse the three samples again to see if the results would be the same, that was however, not done due to lack of time.

Figure 12, Figure 13 and Figure 14 show a schematic view of the results in Table 14. By reviewing all the figures there is no remarkable difference of heavy metal concentration in soil in the greater capital area compared to the other locations.

Hvaleyrarvatn, in the greater capital area has the highest concentrations of Fe and Al according to Figure 12. When the results for the samples for Hvaleyrarvatn are reviewed, in Appendix IV – ICP-MS results for soil samples, it can be seen that the results for sample 3 is relatively higher than sample 1 and 2. Therefore the average concentration for Hvaleyrarvatn is possibly higher for the elements where results for sample 1 are missing. Óslandstjörn has the highest concentration of Ti. According to Figure 13, Urriðavatn has the highest concentration of Mn and Hvaleyrarvatn has the highest concentrations of Cu and Zn. Elliðavatn has the highest concentration of V. Hvaleyrarvatn has the highest concentrations of Cr, Ni and Co according to Figure 14. Óslandstjörn has the highest concentrations of Cd and Pb.

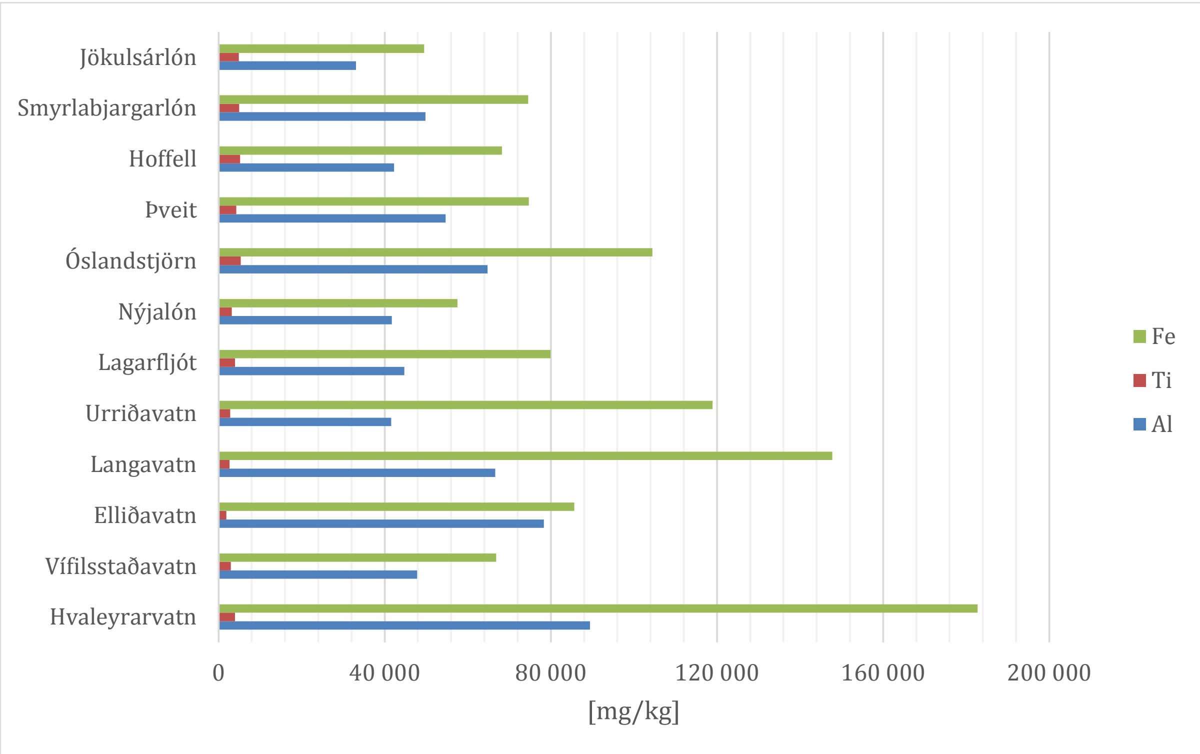

Figure 11 – Schematic view of soil results for Fe, Ti and Al.

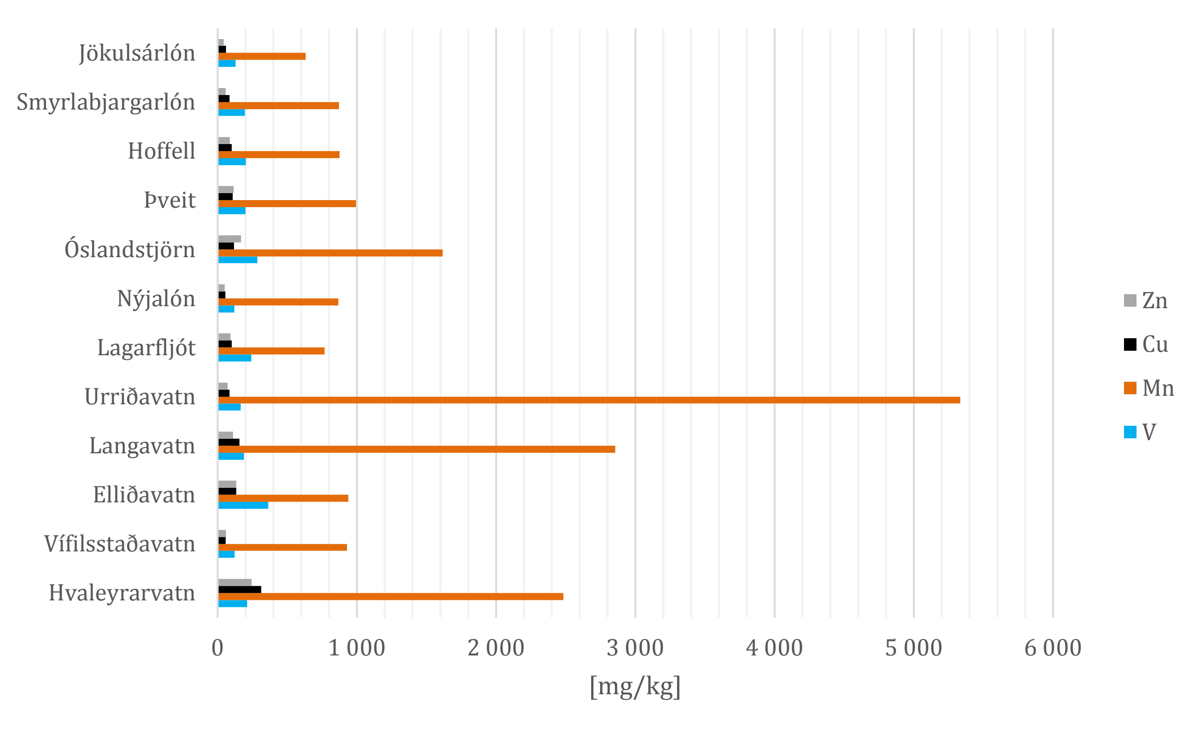

Figure 12 – Schematic view of soil results for Zn, Cu, Mn and V.

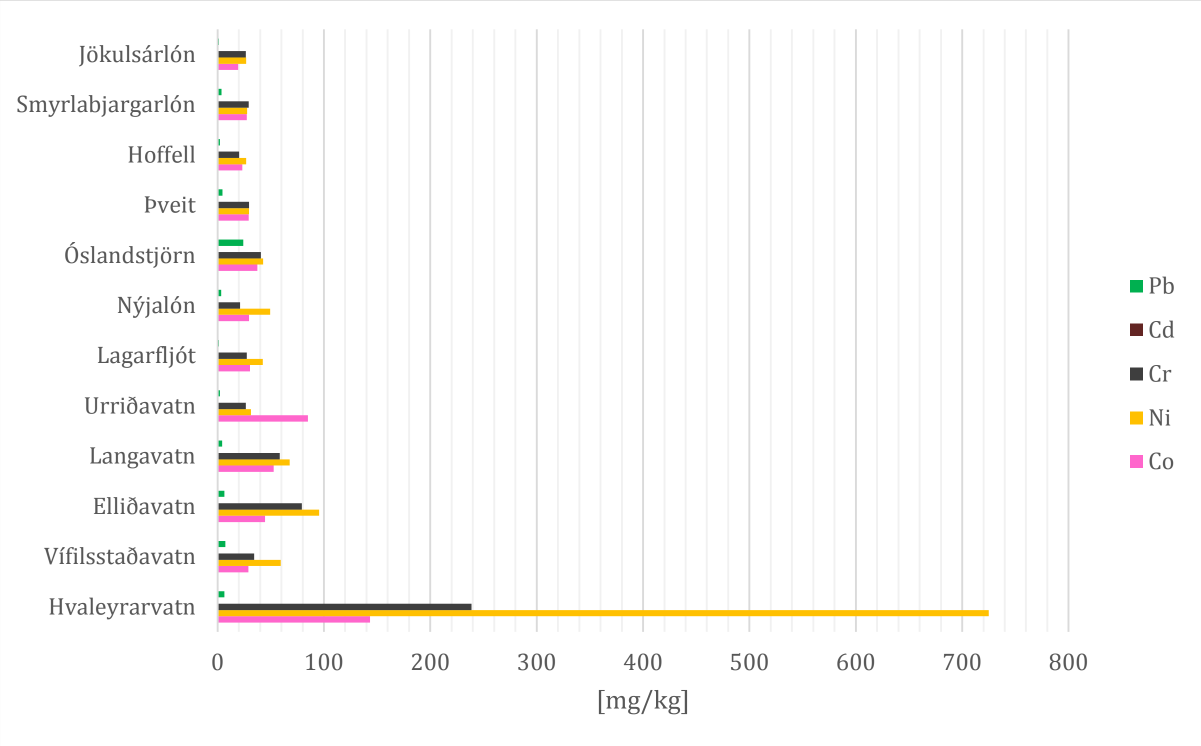

Figure 13 – Schematic view of soil results for Pb, Cd, Cr, Ni and Co.

5.2.1 Correlation analysis

Correlation analysis for the metals that were analysed for soil are shown in Table 15. As previously, the correlation values range between -1 to 1 where -1 is perfect negative correlation and 1 is perfect positive correlation. Values less than 1 have two decimals except for negative values that only have one decimal. Al, Cr, Fe, Co, Ni, Cu, Zn were found to be associated with each other.

Table 15 – Correlation of metals for soil results

	Al	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Cd**	**Sb**	**Pb**	**Sn**
Al	1													
Ti	-0.3	1												
V	0.62	-0.1	1											
Cr	0.81	-0.1	0.24	1										
Mn	0.13	-0.3	-0.1	0.21	1									
Fe	0.74	-0.2	0.22	0.78	0.64	1								
Co	0.65	-0.2	0.10	0.87	0.64	0.88	1							
Ni	0.70	0.0	0.10	0.98	0.20	0.73	0.87	1						
Cu	0.85	0.0	0.35	0.95	0.27	0.87	0.84	0.91	1					
Zn	0.90	0.12	0.55	0.84	0.20	0.77	0.72	0.79	0.91	1				
Cd	0.75	-0.3	0.44	0.39	0.26	0.50	0.37	0.29	0.44	0.63	1			
Sb	0.43	-0.1	-0.2	0.67	0.25	0.64	0.61	0.69	0.61	0.45	0.18	1		
Pt	0.41	0.30	0.42	0.12	0.0	0.20	0.04	0.06	0.15	0.49	0.67	0.08	1	
Pb	-0.2	0.62	0.17	-0.3	-0.2	-0.3	-0.3	-0.2	-0.2	0.08	-0.1	-0.2	0.61	1

5.3 Control samples

Table 16 shows the results for the six control samples containing only MilliQ water and nitric acid. These samples have very low metal concentration and therefore the acid should have minimum effects on the results of the collected water samples.

Table 16 – Results from ICP-MS for the six additional water samples.

	Al	Ti	V	Cr	Mn	Fe	Co
	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
MQ S - 1	6.2	0.03	0.04	-0.03	0.02	-0.89	0.80
MQ S - 2	5.8	0.05	0.04	-0.04	0.02	2.1	0.80
MQ S - 3	6.1	0.04	0.04	0.00	0.02	0.37	0.80
MQ P - 1	7.0	0.04	0.03	0.00	0.02	0.00	0.80
MQ P - 2	5.8	0.08	0.04	0.00	0.02	0.00	0.80
MQ P - 3	9.7	0.06	0.04	0.00	0.02	0.00	0.80
	Ni	**Cu**	**Zn**	**Cd**	**Sb**	**Pt**	**Pb**
	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppt]	[ppb]
MQ S - 1	0.02	0.10	1.57	0.01	0.01	0.67	0.04
MQ S - 2	0.02	0.09	1.48	0.00	0.00	0.37	0.04
MQ S - 3	0.05	2.3	5.8	0.01	0.00	0.30	0.05
MQ P - 1	0.03	1.83	4.5	0.01	0.00	0.63	0.03
MQ P - 2	0.02	1.76	4.5	0.00	0.00	0.00	0.03
MQ P - 3	0.04	2.5	7.1	0.01	0.00	0.56	0.03

5.4 Results accuracy and precision

The accuracy and precision of the results depends on sampling, sample storage, sample preparation and analysis. The human factor plays an important role in precision and accuracy beside the accuracy and precision of the equipment used. The accuracy of ICP-MS is considered to be 3-5%.[11]

Although the initial plan was to use a sediment reference sample to estimate the accuracy of the results, previous results for this sample could not be obtained and the reference sample was therefore not used.

[11] Sebastien Rauch, docent in Civil and Environmental Engineering, Chalmers, oral source, May 20th, 2015

6 Discussion

6.1 Metals in surface water

6.1.1 Comparison with Icelandic regulations

The comparison of the results in Table 12 with the environmental standards in Table 6 indicates that water quality is a concern at several sites. Copper concentration at Lagarfljót and Jökulsárlón reaches environmental standard IV and at Hoffell it reaches environmental standard III. Zinc concentration at Elliðavatn and Nýjalón reaches environmental standard III. The concentrations of other metals do not exceed environmental standard II.

6.1.2 Comparison with previous studies

Previous chemical analyses were found for Lagarfljót, Elliðavatn and Vífilsstaðavatn which are shown in Table 17 along with the results from Table 12 for comparison. Previous analyses were not done in relation to pollution from eruptions. Data from Lagarfljót was obtained from a study for the dam of the Kárahnjúkar hydropower plant. The data for Elliðavatn and Vífilsstaðavatn were obtained in an environmental quality survey.

Table 17 – Average values for comparison. (a) (Eiríksdóttir et al., 2014), (b) (Þórðarson, 2003), (c) (Þórðarson, 2009)

	Lagarfljót 2007-2013 [(a)]	**Lagarfljót 2015**	**Elliðavatn 2009** [(b)]	**Elliðavatn 2015**	**Vífilsstaða-vatn 2009** [(c)]	**Vífilsstaða-vatn 2015**
	Average values [ppb]					
Al	18.2	6 782	-	38	-	21
Ti	3.1	1 182	-	13.1	-	19.2
V	4.9	24	-	2.5	-	2.8
Cr	0.06	4.7	0.56	0.24	0.35	0.49
Mn	1.56	151	-	22	-	6.5
Fe	22	11 152	-	342	-	117
Co	0.02	3.6	-	1.11	-	0.83
Ni	0.10	4.3	0.16	0.67	0.48	0.24
Cu	0.35	16.8	0.49	1.36	1.45	0.50
Zn	0.59	13.0	0.45	39	7.6	1.72
Cd	<0.0028	0.02	0.01	0.02	<0.074	0.01
Pb	<0.012	0.14	0.03	0.10	<0.44	0.05

Concentrations of all metals have increased at Lagarfljót compared to concentrations measured in 2007-2013, which will be discussed further in chapter 6.1.3. The increase ranges from ca. 20 times for Zn to ca. 500 times for Fe. The concentrations of Al, Ti, Co and Fe have increased more than 100 times. In contrast, there are no drastic changes in metal concentration of metals at Elliðavatn except from the large increase in concentration of Zn. The metal concentration in Vífilstaðavatn has decreased except for Cr concentration. Elliðavatn and Vífilstaðavatn are however located in the greater capital area where severe changes were not expected.

6.1.2.1 Concentrations in glacial water

Sampling sites that receive water directly from Vatnajökull glacier, i.e. Jökulsárlón, Hoffell and Lagarfljót, have high concentrations of metals. These sampling sites have the highest concentrations of Ti, Cu, V and Ni according to the results shown in Figure 8, Figure 9 and Figure 10. The reason for this is not known. Possible explanations could be their closeness to the glacier and Holuhraun. Air pollution could be higher at these locations and in their catchment areas. The previous chemical analysis in Table 17 shows that the concentration in Lagarfljót is usually not higher than in the other lakes. There is no previous available data for Hoffell and Jökulsárlón and therefore it cannot be stated if glacial water has usually higher heavy metal concentration compared to other lakes.

Comparing the results in Table 12 to the chemical analysis on glacial water in Table 2 shows that the concentration of Fe is significantly higher in this analysis. The concentration of Fe is even higher at all sampling sites. Comparing the concentrations of Zn, Mn, and Pb shows that there is no remarkable difference.

Vatnajökull glacier covers some of the main volcanoes in Iceland (Grímsvötn and Bárðarbunga) and therefore the glacial ice contains traces of many previous eruptions.

6.1.3 High concentrations in Lagarfljót

Lagarfljót's origin is a glacial river flowing from Eyjabakkajökull glacier a part of Vatnajökull glacier, see Figure 5. Lagarfljót is 53 km^2 and the third largest natural lake in Iceland. The total catchment area is 2 900 km^2 and about 140 km^2 are a part of Vatnajökull glacier (Rist, 1990). The catchment area can consequently be considered relatively large. Data from the Icelandic Meteorological office shows that the week before sample collection the temperature was always above 0°C and up to 11°C as can be seen in Appendix V – Weather data for Egilsstaðir. The high concentration of metals could therefore be because of polluted snow on the catchment area that was delivered to the river. Lagarfljót is closest to Holuhraun of all the sampling sites and therefore expected to have the highest concentration.

More samples would be needed at different locations from Lagarfljót's origin down to where the sample was collected to confirm the suspicion. Signs of other possible pollution sources would also have to be researched.

6.2 Drinking water

The results in Table 12 show that metal concentration in the drinking water is not of concern when compared to the maximum values in Table 7. However a high concentration of Zn indicates that it might be because of leaching from the pipes where the sample was collected. Even though the water had been running for a few minutes, before the samples were collected, to avoid this problem. The concentration of Zn in surface water is usually no more than 10 µg/litre (10 ppb) (World Health Organization, 2003).

The Department of Environment in the East has been notified of the results and agrees that possible reason for high Zn concentration is leaching from pipes since it has been noticed before.[12] With higher concentration (3000 ppb) the drinking water could have an undesirable taste (World Health Organization, 2003).

Since no data for previous chemical analysis exists it is not possible to predict if there have been changes in chemical concentrations in the drinking water. It would have been preferable to collect the drinking water sample before the water enters the distribution system.

6.3 Metals in soil

6.3.1 Comparison with Icelandic guidelines

Comparison of the results in Table 14 with the Icelandic guidelines in Table 8 shows that the results of the collected samples are compatible to the background values in the guideline.

The concentrations of Cd, Cr and Pb, in the collected samples, never reach the lower threshold in the guidelines. Concentration of Ni is above the lower threshold at all locations and Hvaleyrarvatn reaches over the upper threshold. Zn values are compatible with the background values, only Hvaleyrarvatn and Smyrlabjargarlón reach over the lower threshold.

6.3.2 Comparison with previous studies

When the results for soil in Table 14 are compared to world soil average concentration in Table 3 it can be seen that the soil samples from Iceland have, in most cases, higher concentrations of trace metals.

For all sampling sites, the concentrations of Mn, Co and Cu are higher than for the world soil average. However there are no world soil average values for Al and Fe and therefore it is difficult to evaluate and cannot be compared.

Further, Table 4, showing concentration of heavy metals in La Réunion, does not contain any values for Al and Fe. However, the results for soil in Table 14 are compatible to the values in Table 4. Concentration of Cu is always higher than the mean value except for at Nýjalón where it is close to the mean value.

Majority of the results in Table 14 are higher than the values in Table 5 which shows the concentration of heavy metals in Solofrana river valley, except for concentration of Pb.

After comparing the results with these three tables (Table 3, Table 4 and Table 5) it is considered that the concentrations in the Icelandic soil are high.

[12] Leifur Þorkelsson, Food inspection and pollution control at the Department of Environment in the East, oral source, March 30th, 2015

6.4 Correlation analysis

Positive correlation can indicate if the metal concentration has the same source. Table 13 shows that the correlation between Al, Ti, Cr, Fe, Co and Ni is good in the water samples when values higher than 0.9 are examined. The concentration of metals does not correlate as well in the soil samples, see Table 15. Values higher than 0.9 are however for Cr, Cu, Ni and Zn which are the exact same metals that were mentioned in chapter 3.3, because Icelandic soil is rich of these elements

These results indicate that concentrations of Al, Ti, Cr, Fe, Co and Ni in surface water have the same source, likely the eruption in Holuhraun. The results for the soil are more likely a general trend for Icelandic soil, although some could be related to the eruption.

6.5 General discussion on surface water and soil results

The soil samples have higher concentration of heavy metals than the water samples. That was expected since soil contains naturally much more heavy metals.

Unlike the results for the water samples, the samples collected in the greater capital area do not have lower concentrations of Fe, Ti and Al compared to other sampling sites according to Figure 12. The glacier lagoons, Jökulsárlón and Hoffell, and the glacial river Lagarfljót do not have the highest concentrations of Ti, Cu, V and Ni in soil as the results for surface water showed. The concentrations in soil in Lagarfljót are not the highest as it was for the water samples. That indicates that the pollution is relatively new and has not yet affected the soil. No other pollution pattern was found, e.g. in relation to distance from the eruption. Therefore there is no indication that the soil is polluted from the eruption in Holuhraun.

Sudden acidic episodes and related metals can be more harmful to the ecosystem than when the pH-value has slowly decreased. The length and timing of the acidic episode is important for the ecosystem. However, how the Icelandic water ecosystems react to acidic episodes related to eruptions is unknown.[13]

The life expectancy of salmon fry is considered to decrease by 50% when aluminium concentration reaches 11 µmol/l (297 ppb).[14] The concentration of aluminium at Lagarfljót is much higher.

Lagarfljót is not used as a drinking water source and the concentration of the metals is therefore not a direct concern for humans. However there is some fish in the river, for example; salmon, arctic char and trout (Jónsson & Árnason, 2011). The effect that the pollution has on the fauna in Lagafljót depends on the period of the high metal concentrations, both timing and duration.

[13] Halla Margrét Jóhannesdóttir, scientist at Institute of Freshwater Fisheries, Áhrif eldgossins á lífríki í ám og vötnum. [Effect of the eruption on ecosystem in freshwater], seminar regarding the eruption in Holuhraun, March 23rd, 2015

[14] Eydís Salóme Eiríksdóttir, PhD student at University of Iceland, Mengun yfirborðsvatns. [Surface water pollution], seminar regarding the eruption in Holuhraun, March 23rd, 2015

The eruption in Holuhraun emitted large amount of gas and lava, however no tephra. Tephra eruptions with lava flow are more common in Iceland and their effects on the environment are therefore better known up to a certain degree. The location of the eruption was fortunate since there is not much flora surrounding the eruption site. Little is known about how the eruption affected wild mammals and birds except for the few mice and birds that died as previously mentioned. The only wild mammals in the eastern part of Iceland are rodents, arctic foxes, minks and reindeers.[15]

[15] Sigurður H. Magnússon, Plant Ecologist at the Icelandic Institute of Natural History, Áhrif eldgossins á villt dýr og vistkerfi. [Effects of the eruption from Holuhraun on the wildlife ecosystem], seminar regarding the eruption in Holuhraun, March 23rd, 2015

7 Conclusion

Water and soil samples were collected, following the eruption in Holuhraun, and analysed to determine metal concentrations. The soil sample results indicate that there is no or limited pollution in the soil that can be connected to the eruption in Holuhraun. The concentrations are comparable to the background values of Icelandic soil and there is no visible difference in concentrations in the greater capital area and the other sampling sites in the area where the volcano might have had a larger impact. The timing of the eruption was also fortunate for flora since the growth period was almost over.

The concentration of heavy metals in the water samples for the greater capital area is lower for some elements than for the other locations. That indicates possible pollution from the eruption in surface water in the eastern part of Iceland. Correlation analysis also indicates that surface water is polluted because of the eruption.

Sampling sites that receive water directly from Vatnajökull glacier have notably higher concentrations for some of the heavy metals that were analysed. The glacial river, Lagarfljót, has the highest concentration of heavy metals in surface water which strongly indicates pollution from the eruption in Holuhraun. The reason for higher concentrations in Lagarfljót can be explained by its large catchment area and closeness to the eruption site. Comparing the results with previous analysis in Lagarfljót shows large increase of heavy metal concentration. Other possible pollution source would have to be researched in order to confirm that the eruption is the cause of this pollution. Previous results were not available for most of the sampling sites which makes it harder to identify increase in concentrations.

The results for the drinking water samples collected in Seyðisfjörður indicate leaching from pipes. It would have been preferable to collect samples before the water enters the distribution network to avoid contamination from pipes.

It would be interesting to analyse the concentration of heavy metals when the snow melts in the spring. This analysis could be used for comparison. However, due to many storms with heavy rain and high temperature, during the winter 2014-2015, the concentration peak will possibly be lower in the spring since some of the polluted snow has already melted.

The University of Iceland and the Environmental Agency of Iceland research eruptions and their environmental impacts. Researches done in relation to the eruption in Holuhraun had not been published when this thesis was written. The results will, however, be useful for future eruptions of this kind and to evaluate the environmental impact the eruption had.

8 References

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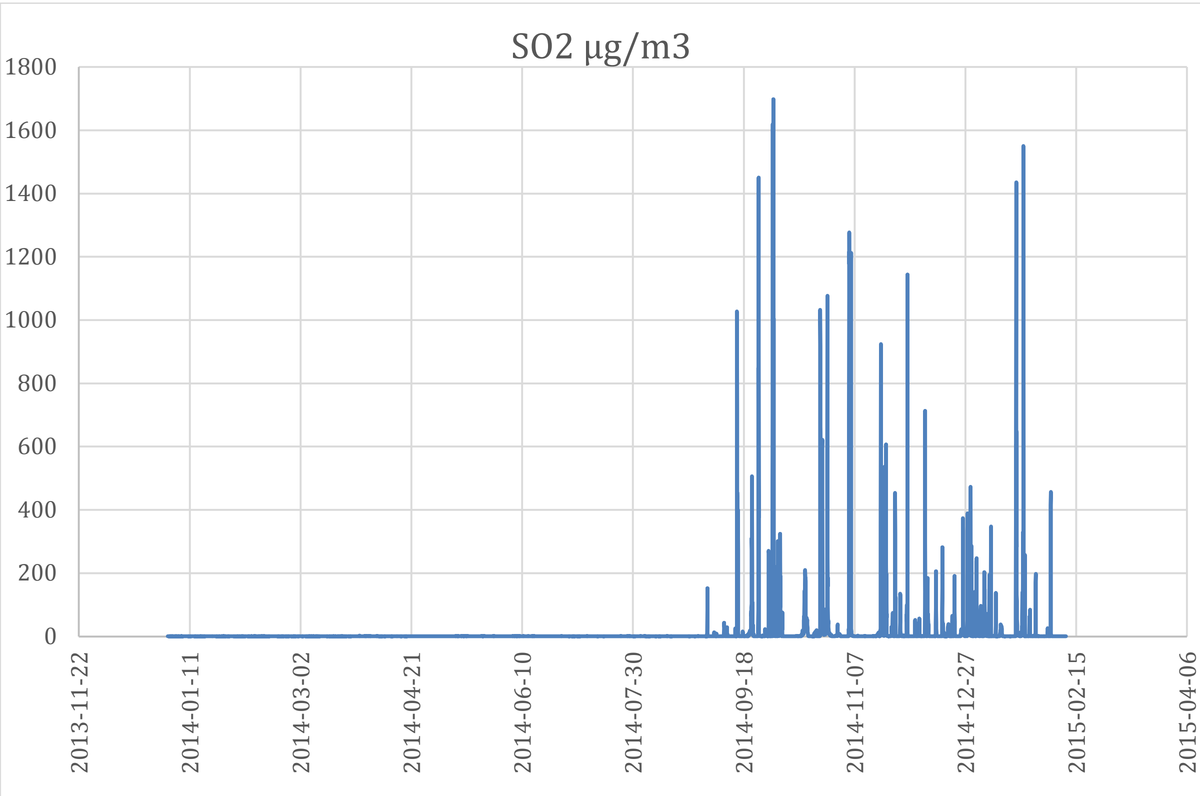
9 Appendices

9.1 Appendix I – Data on SO_2 concentration

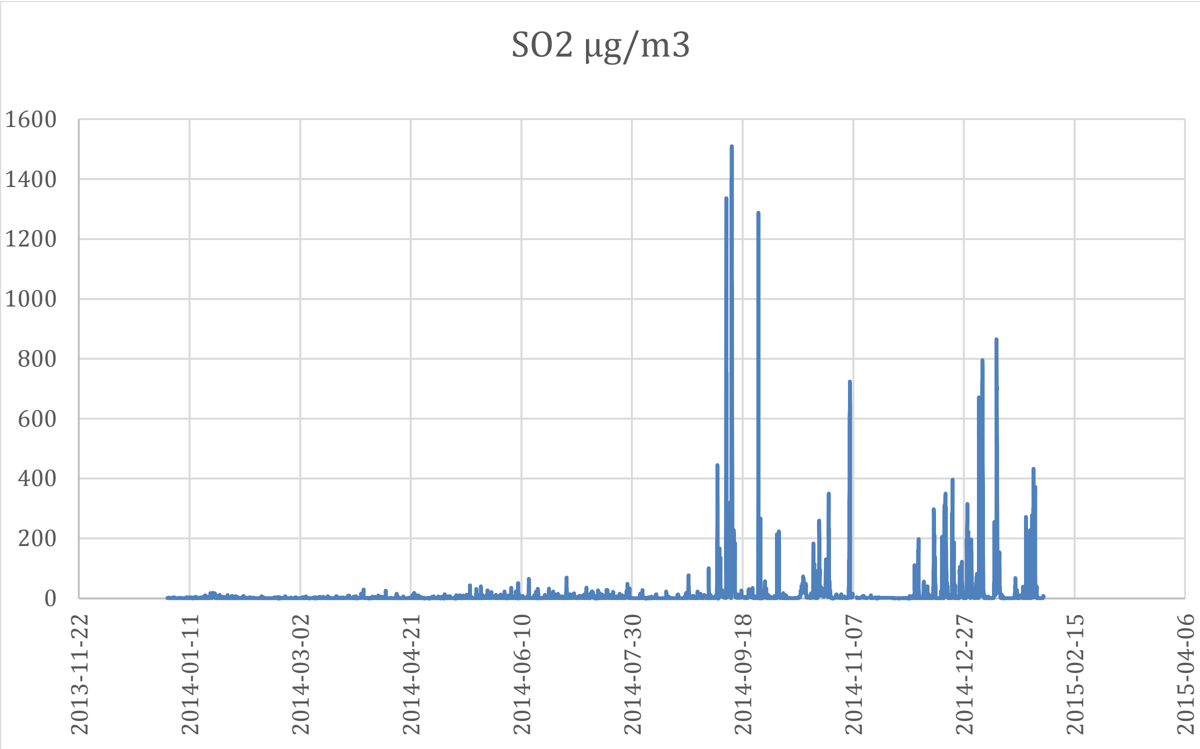
Reykjahlíð, Elementary school

From beginning og eruption 31st of August 2014 until 1st of February 2015			
Max	1697.7		
Min	-0.1		
Average	29.9		
Numer of measurements	3661		
Number equal or higher than 350 µg/m3	84	3.50	days
% of measurements=>350	2.29		
	109		
Accumulated	475		



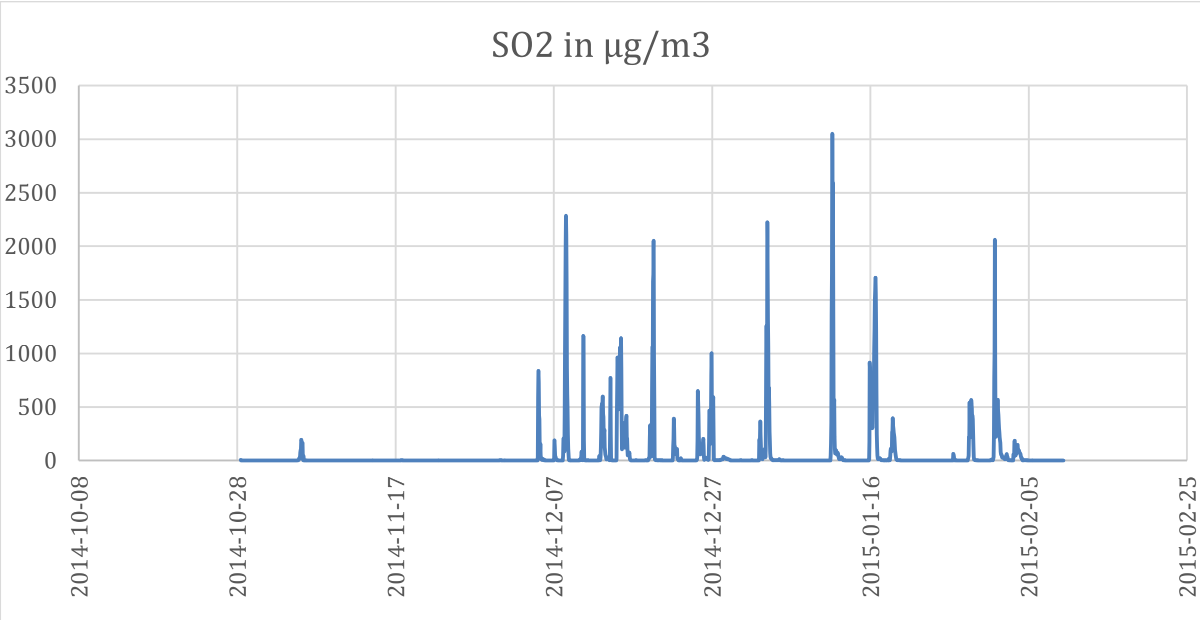
Reyðarfjörður – Hjallaleyra

From the begining of the eruption 31st of August 2014 until 1st of February 2015			
Max	1509.3		
Min	-1.8		
Average	31.6		
Numer of measurements	3601		
Number equal or higher than 350 µg/m3	52	2.17	days
% of measurements=>350	1.44		
	113		
Accumulated	905		



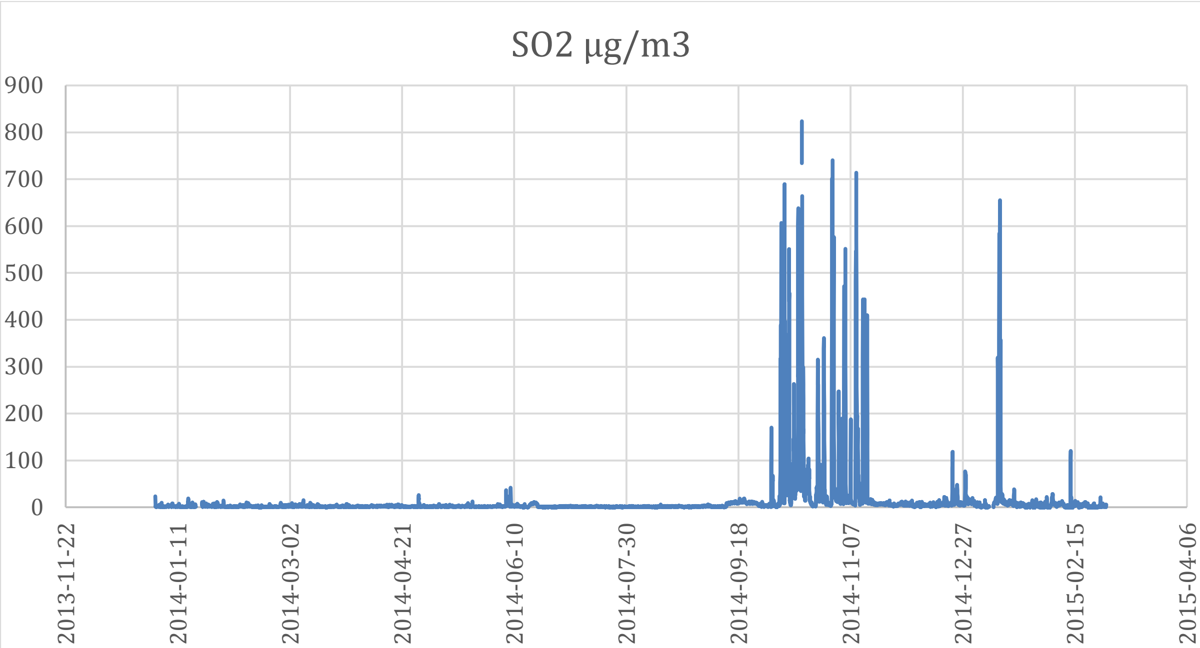
Höfn

From begining of measuremants until 1st of February 2015			
Max	3050		
Min	-0.869		
Average	58.2		
Numer of measurements	2294		
Number equal or higher than 350 µg/m3	119	4.96	days
% of measurements=>350	5.19		
Accumulated	133 425		



Reykjavík – Grensás

From the beginning of the eruption on 31st of August 2014 until 21st of February 2015			
Max	823.5		
Min	-0.7		
Average	29.7		
Numer of measurements	3366		
Number equal or higher than 350 µg/m3	59	2.46	days
% of measurements=>350	1.75		
Accumulated	100 018		



9.2 Appendix II – Drinking water data for Seyðisfjörður

date	Type of sample (DRINKING WATER 1)	Water treatment plant	Sampling site	Sampling reason	Bacteria count at 22°C in 1 ml	E.coli in 100 ml	pH-value
16-feb	Radiated (UV)	Seyðisfjarðar	Shellskálinn	Regular monitoring	1	0	7.47
21-mar	Radiated (UV)	Seyðisfjarðar	Ránargata 15	Regular monitoring	0	0	7.41
08-okt	Radiated (UV)	Seyðisfjarðar	Brimberg	Regular monitoring	24	0	7.12
25-mar	Radiated (UV) water	Seyðisfjarðar	Samkaup Strax	Regular monitoring	1	1	7.29
08-apr	Radiated (UV) water	Seyðisfjarðar	Samkaup Strax	Repetition	0	0	7.2
03-jul	Radiated (UV) water	Seyðisfjarðar	Brimberg	Regular monitoring	4	0	8.47
25-nov	Radiated (UV) water	Seyðisfjarðar	Brimberg	Total evaluation	0	0	7.4
16-jan	Radiated water	Seyðisfjarðar	Samkaup	Regular monitoring	1	0	7.19
05-maj	Radiated water	Seyðisfjarðar	Botnahlíð 33	Regular monitoring	0	0	7.31
05-aug	Radiated water	Seyðisfjarðar	Brimberg	Regular monitoring	3	0	6.7
04-sep	Radiated water	Seyðisfjarðar	Brimberg	Survey	4	0	7.55
04-sep	Radiated water	Seyðisfjarðar	Shell skálinn	Survey	11	0	7.39
04-sep	Radiated water	Seyðisfjarðar	HSA Seyðisfirð	Survey	12	0	7.39
16-sep	Radiated water	Seyðisfjarðar	Vatnshreinsistöð	Survey			7.1
22-sep	Radiated water	Seyðisfjarðar	íþróttahús	Survey	0	0	6.22
26-sep	Radiated water	Seyðisfjarðar	bæjarskrifstofa	Survey			7
26-sep	Radiated water	Seyðisfjarðar	áhaldahús	Survey			7.12
03-okt	Radiated water	Seyðisfjarðar	íþrótahús	Survey			7.15
04-nov	Radiated water	Seyðisfjarðar	Dæluskúr	Regular monitoring	4	0	6.5
04-nov	Radiated water	Seyðisfjarðar	Áhaldahús	Survey	2	0	7.05
02-dec	Radiated water	Seyðisfjarðar	Íþróttahús	Other			6.43
08-dec	Radiated water	seyðisfj	íþróttahús	Other			7.25

9.3 Appendix III – ICP-MS results for water samples

	27Al (KED)	48Ti (KED)	51V (KED)	52Cr (KED)	55Mn (KED)	57Fe (KED)	59Co (KED)
	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)
Sample 40	6.21	0.03	0.04	-0.03	0.02	-0.89	0.80
Sample 1	52.48	7.14	0.21	0.07	33.41	57.57	0.92
Sample 2	63.84	8.52	0.21	0.05	30.80	59.98	0.91
Sample 3	78.51	9.60	0.23	0.06	29.34	79.37	0.91
Sample 4	18.37	19.13	2.70	0.52	6.56	113.24	0.84
Sample 5	22.25	19.38	2.78	0.48	6.43	119.73	0.83
Sample 6	21.73	19.23	2.76	0.46	6.47	118.62	0.83
Sample 7	17.51	9.04	0.15	0.04	11.41	91.21	1.03
Sample 8	47.02	14.67	3.60	0.33	26.85	462.03	1.14
Sample 9	50.80	15.68	3.82	0.36	29.30	475.68	1.17
Sample 10	79.08	29.28	0.52	0.07	76.83	1 192.99	1.00
Sample 11	281.59	65.19	1.91	0.23	123.96	4 960.56	1.20
Sample 12	22.08	19.49	0.25	0.01	69.34	693.04	0.96
Sample 13	21.97	15.86	0.27	0.01	69.45	471.50	1.14
Sample 14	17.74	15.36	0.24	-0.01	41.78	311.68	0.99
Sample 15	19.99	15.75	0.25	0.25	41.19	319.33	1.01
Sample 16	6 651.61	1 154.47	25.40	4.63	125.30	11 096.05	3.60
Sample 17	6 892.41	1 272.85	25.65	5.02	170.38	11 866.90	3.69
Sample 18	6 802.71	1 119.34	23.61	4.29	159.55	10 493.61	3.43
Sample 19	235.25	31.21	1.25	0.25	72.36	794.78	0.96
Sample 41	5.80	0.05	0.04	-0.04	0.02	2.09	0.80
Sample 20	974.34	117.45	7.40	1.14	142.06	7 985.58	1.40
Sample 21	282.73	33.16	1.37	0.26	39.82	835.21	0.97
Sample 22	52.66	10.42	0.76	0.20	8.02	930.81	0.86
Sample 23	55.61	9.28	0.75	0.09	7.45	913.37	0.84
Sample 24	52.30	10.42	0.79	0.18	7.88	919.46	0.85
Sample 25	22.53	16.20	0.37	-0.01	83.97	277.87	0.85
Sample 26	1 671.24	216.85	7.64	1.32	195.36	3 547.35	2.07
Sample 27	18.14	16.56	0.42	0.00	96.52	265.04	0.83
Sample 28	1 272.84	286.39	23.30	1.24	30.22	2 264.78	1.67
Sample 29	1 373.83	277.83	24.25	1.14	31.42	2 314.41	1.71
Sample 30	1 318.10	251.39	24.23	1.17	42.35	2 224.05	1.65
Sample 31	243.12	27.45	1.57	0.28	38.55	560.91	1.05
Sample 32	395.80	56.57	2.18	0.20	43.52	594.67	1.04
Sample 33	302.29	39.68	1.91	0.19	47.89	584.28	1.06
Sample 34	127.23	398.44	8.08	0.21	14.92	127.08	0.91
Sample 35	121.82	430.68	8.82	0.36	16.95	142.09	0.87
Sample 36	146.60	484.54	9.75	0.30	18.12	158.61	0.92
Sample 37	15.28	9.61	0.48	0.00	10.56	129.40	0.94

	27Al (KED)	48Ti (KED)	51V (KED)	52Cr (KED)	55Mn (KED)	57Fe (KED)	59Co (KED)
	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)
Sample 38	15.06	8.62	0.44	0.00	10.43	123.66	0.94
Sample 39	19.14	8.89	0.45	0.07	10.41	121.64	0.95
Sample 42	6.07	0.04	0.04	0.00	0.02	0.37	0.80
Sample 43	7.04	0.04	0.03	0.00	0.02	0.00	0.80
Sample 44	5.84	0.08	0.04	0.00	0.02	0.00	0.80
Sample 45	9.71	0.06	0.04	0.00	0.02	0.00	0.80

	60Ni (STD)	63Cu (STD)	66Zn (STD)	111Cd (STD)	121Sb (KED)	195Pt (KED)	208Pb (STD)
	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppt)	Y (ppb)
Sample 40	0.02	0.10	1.57	0.01	0.01	0.67	0.04
Sample 1	0.29	0.66	2.63	0.01	0.00	0.73	0.06
Sample 2	0.27	0.60	2.09	0.01	0.00	0.00	0.05
Sample 3	0.36	0.72	3.30	0.01	0.00	0.34	0.09
Sample 4	0.25	0.76	1.92	0.01	0.00	0.99	0.06
Sample 5	0.23	0.37	1.55	0.01	0.00	1.54	0.04
Sample 6	0.23	0.37	1.69	0.01	0.00	0.72	0.04
Sample 7	0.81	0.72	2.64	0.01	0.01	0.00	0.10
Sample 8	0.62	1.90	64.72	0.02	0.04	0.95	0.10
Sample 9	0.57	1.46	50.68	0.02	0.03	0.51	0.11
Sample 10	0.49	0.57	4.27	0.01	0.00	1.92	0.05
Sample 11	0.63	0.96	5.01	0.01	0.00	1.22	0.05
Sample 12	0.37	0.41	4.75	0.01	0.00	0.33	0.05
Sample 13	0.37	0.67	1.51	0.01	0.00	0.00	0.05
Sample 14	0.32	0.55	5.34	0.01	0.00	1.36	0.04
Sample 15	0.31	0.56	6.53	0.01	0.00	0.77	0.05
Sample 16	4.30	16.64	12.02	0.03	0.00	0.81	0.14
Sample 17	4.57	17.66	13.51	0.02	0.00	0.49	0.14
Sample 18	4.13	16.13	13.50	0.02	0.00	1.03	0.15
Sample 19	0.64	1.23	18.32	0.04	0.00	0.47	0.15
Sample 41	0.02	0.09	1.48	0.00	0.00	0.37	0.04
Sample 20	2.40	5.94	47.30	0.17	0.00	0.00	0.44
Sample 21	0.92	1.41	40.40	0.08	0.00	0.27	0.20
Sample 22	1.18	1.28	11.93	0.01	0.05	0.00	0.13
Sample 23	0.50	0.85	6.28	0.01	0.00	0.00	0.09
Sample 24	0.85	1.17	7.82	0.01	0.03	0.00	0.11
Sample 25	0.22	0.28	1.63	0.01	0.00	0.00	0.03
Sample 26	2.11	3.82	9.90	0.04	0.00	0.01	0.21
Sample 27	0.24	0.29	1.55	0.01	0.00	1.19	0.05
Sample 28	1.43	4.60	6.33	0.01	0.02	0.00	0.09
Sample 29	1.59	4.84	7.00	0.01	0.03	1.79	0.09

	60Ni (STD)	63Cu (STD)	66Zn (STD)	111Cd (STD)	121Sb (KED)	195Pt (KED)	208Pb (STD)
	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppt)	Y (ppb)
Sample 30	1.45	4.94	4.03	0.02	0.01	2.44	0.10
Sample 31	0.41	1.42	2.60	0.01	0.00	0.00	0.07
Sample 32	0.41	1.43	2.73	0.01	0.00	0.29	0.08
Sample 33	0.46	1.43	4.63	0.01	0.00	0.74	0.07
Sample 34	2.16	18.28	3.64	0.02	0.28	0.00	0.05
Sample 35	2.05	28.35	1.45	0.02	0.16	0.44	0.04
Sample 36	2.08	37.42	2.33	0.04	0.18	0.00	0.03
Sample 37	0.45	3.80	1 579.61	0.04	0.00	0.00	0.26
Sample 38	0.52	4.23	1 840.25	0.03	0.00	0.57	0.29
Sample 39	0.44	3.40	1 548.81	0.03	0.00	0.59	0.29
Sample 42	0.05	2.33	5.80	0.01	0.00	0.30	0.05
Sample 43	0.03	1.83	4.46	0.01	0.00	0.63	0.03
Sample 44	0.02	1.76	4.53	0.00	0.00	0.00	0.03
Sample 45	0.04	2.48	7.14	0.01	0.00	0.56	0.03

9.4 Appendix IV – ICP-MS results for soil samples

	Cr (KED)	Ni (STD)	Cu (STD)	Zn (STD)	Cd (STD)	Pb (STD)	Al (STD)
	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)
Sample 1	58.16	120.57	77.07	53.80	0.07	1.21	
Sample 2	28.65	90.36	32.07	22.86	0.01	0.42	14 190.69
Sample 3	137.13	469.09	184.79	152.02	0.15	4.45	69 584.80
Sample 4	18.50	38.21	33.13	26.94	0.08	2.97	23 485.75
Sample 5	13.79	17.51	22.38	30.18	0.09	3.98	21 306.60
Sample 6	0.00	0.00	0.00	0.00	0.00	0.00	3.57
Sample 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sample 8	16.84	26.87	36.87	56.60	0.09	4.42	19 559.16
Sample 9	57.32	62.61	89.49	68.21	0.15	1.52	53 835.35
Sample 10	15.54	12.88	26.49	27.78	0.03	0.44	18 222.98
Sample 11	3.88	6.28	25.97	14.30	0.08	0.93	2 480.68
Sample 12	35.42	44.51	95.69	63.04	0.11	2.82	41 728.97
Sample 13	5.98	9.49	31.70	24.95	0.04	0.95	9 985.58
Sample 14	4.09	10.11	20.40	19.90	0.05	0.60	7 074.24
Sample 15	14.77	9.97	28.72	23.73	0.05	0.53	21 984.12
Sample 16	8.08	12.44	30.89	23.73	0.02	0.38	13 682.38
Sample 17	8.57	12.91	29.42	31.63	0.00	0.48	12 064.44
Sample 18	8.97	14.44	35.49	31.50	0.02	0.50	16 064.60
Sample 19	11.76	18.40	27.83	24.01	0.11	1.83	19 151.44
Sample 20	8.38	28.40	24.51	23.53	0.06	1.31	20 254.56
Sample 21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sample 22	6.47	7.28	19.93	25.35	0.04	2.93	12 337.50
Sample 23	8.83	8.54	27.15	42.13	0.08	4.13	13 356.47
Sample 24	22.97	24.28	63.10	89.94	0.16	15.56	34 949.54
Sample 25	8.81	8.56	28.20	49.93	0.11	2.86	16 346.45
Sample 26	6.66	8.12	40.98	20.09	0.03	0.47	14 921.80
Sample 27	12.35	11.02	33.72	39.58	0.06	0.96	20 020.29
Sample 28	5.20	6.89	26.75	20.72	0.02	0.55	11 844.65
Sample 29	6.32	8.19	31.00	28.59	0.03	0.73	12 551.88
Sample 30	7.50	10.21	37.69	33.84	0.05	0.76	15 282.72
Sample 31	10.86	8.27	29.38	16.97	0.04	1.13	16 723.67
Sample 32	100.39	92.07	292.24	196.46	0.62	11.36	88 285.97
Sample 33	7.53	9.10	24.81	18.83	0.02	1.22	14 393.90
Sample 34	8.01	9.47	23.24	17.99	0.03	0.49	10 607.32
Sample 35	7.85	8.25	18.50	13.71	0.02	0.45	10 435.31
Sample 36	9.10	7.69	15.07	10.61	0.01	0.30	10 055.53

	Ti (KED)	V (KED)	Mn (KED)	Fe (KED)	Co (KED)	Sn (STD)	Sb (KED)
	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)	Y (ppb)
Sample 1							
Sample 2	742.96	35.43	326.77	26 896.67	19.32	0.34	0.03
Sample 3	2 955.18	164.37	2 001.31	144 378.90	114.96	1.33	0.02
Sample 4	2 416.30	65.56	408.51	29 837.64	14.29	1.04	0.03
Sample 5	382.05	50.31	462.49	32 778.94	12.92	1.26	0.01
Sample 6	0.26	0.01	0.13	10.54	0.02	0.04	0.00
Sample 7	0.00	0.00	0.00	0.88	0.01	0.04	0.00
Sample 8	1 522.10	66.91	189.25	19 459.41	10.26	1.33	0.01
Sample 9	265.63	275.26	690.12	60 817.99	31.69	0.13	0.00
Sample 10	1 621.28	59.22	484.90	45 588.49	10.64	0.35	0.00
Sample 11	484.13	44.78	1 325.31	30 171.53	11.09	0.70	0.03
Sample 12	370.02	73.60	866.24	62 713.20	27.72	0.09	0.00
Sample 13	1 390.47	62.85	1 621.20	42 290.14	26.18	0.98	0.01
Sample 14	929.23	46.05	2 929.49	41 365.92	42.10	0.54	0.01
Sample 15	320.70	47.94	468.14	28 203.39	11.56	0.50	0.00
Sample 16	1 228.24	66.03	219.67	23 027.46	8.91	0.89	0.01
Sample 17	1 547.25	91.27	245.86	25 410.49	9.55	1.02	0.00
Sample 18	905.36	68.91	253.14	26 299.80	10.07	0.89	0.00
Sample 19	2 055.56	65.21	465.48	27 213.73	12.99	0.85	0.00
Sample 20	971.74	49.26	355.70	27 186.61	14.90	0.69	0.00
Sample 21	0.12	0.00	0.02	2.57	0.06	0.04	0.00
Sample 22	1 690.95	58.77	250.68	17 936.46	6.37	1.10	0.01
Sample 23	1 596.30	60.54	432.31	21 373.94	8.11	0.72	0.00
Sample 24	1 711.49	147.84	831.43	58 486.09	20.56	1.69	0.00
Sample 25	1 940.16	69.28	308.96	25 069.92	8.86	1.31	0.01
Sample 26	1 533.52	58.66	166.73	15 886.35	7.37	0.88	0.00
Sample 27	561.40	61.44	455.64	29 152.98	11.15	0.09	0.00
Sample 28	1 778.69	58.80	250.87	19 516.30	6.73	0.95	0.02
Sample 29	1 972.25	70.43	265.21	20 915.03	6.97	0.82	0.00
Sample 30	1 121.28	60.33	306.68	23 612.03	8.20	0.22	0.00
Sample 31	2 335.14	70.23	301.57	24 503.32	9.00	1.09	0.01
Sample 32	15 099.40	514.78	2 971.35	215 319.40	84.26	4.00	0.01
Sample 33	787.91	52.82	243.11	22 082.71	8.19	0.13	0.00
Sample 34	1 863.39	47.96	221.13	17 639.77	6.72	0.76	0.01
Sample 35	1 600.67	41.50	202.06	15 699.41	6.14	0.75	0.00
Sample 36	1 095.96	33.31	171.83	13 203.26	5.44	0.64	0.01

9.5 Appendix V – Weather data for Egilsstaðir

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	*°C*	*°C*	*%*	*degrees*	*m/s*	*m/s*	*m/s*	*mm*
2	2	1	-6.8	-6.7	-7.0	93	146	0.1	1.4	2.2	0.0
2	2	2	-6.6	-6.6	-6.9	94	121	0.2	0.8	1.2	0.0
2	2	3	-5.5	-5.3	-6.6	94	356	1.1	1.1	3.1	0.3
2	2	4	-4.4	-4.4	-5.7	96	16	5.7	5.7	7.6	0.1
2	2	5	-3.5	-3.5	-4.6	96	27	4.5	5.0	8.5	0.0
2	2	6	-3.9	-3.4	-4.2	96	5	9.8	10.8	13.2	0.0
2	2	7	-4.2	-3.9	-4.3	96	8	8.3	10.2	12.5	0.0
2	2	8	-4.9	-4.2	-4.9	95	8	5.1	9.9	11.5	0.0
2	2	9	-5.0	-4.8	-5.2	95	12	5.7	7.1	8.9	0.0
2	2	10	-4.8	-4.5	-5.2	79	338	6.0	8.0	9.6	0.0
2	2	11	-5.4	-4.4	-5.4	70	331	3.9	6.5	8.1	0.0
2	2	12	-5.0	-4.4	-5.4	63	6	1.6	5.5	7.3	0.0
2	2	13	-5.1	-4.6	-5.4	69	12	3.1	5.2	10.9	0.0
2	2	14	-5.3	-5.0	-5.8	82	1	8.2	9.3	11.6	0.0
2	2	15	-5.9	-5.3	-6.4	69	38	5.5	9.5	12.2	0.0
2	2	16	-7.1	-5.8	-7.1	67	330	9.2	9.2	12.2	0.0
2	2	17	-7.3	-7.1	-7.5	68	342	10.5	10.5	13.5	0.0
2	2	18	-7.3	-7.2	-7.7	64	7	4.5	11.7	14.7	0.0
2	2	19	-7.2	-7.1	-7.4	68	328	5.8	7.4	10.1	0.0
2	2	20	-7.2	-7.0	-7.4	70	331	3.0	6.1	9.0	0.0
2	2	21	-9.3	-6.8	-9.3	71	70	1.8	3.8	5.5	0.0
2	2	22	-8.7	-8.1	-9.6	72	106	2.7	2.7	4.2	0.0
2	2	23	-7.8	-7.2	-9.0	68	162	1.8	2.4	3.9	0.0
2	2	24	-5.2	-5.1	-8.1	69	304	8.0	8.0	12.0	0.0
2	3	1	-5.0	-4.8	-5.3	68	300	7.6	8.5	12.5	0.0
2	3	2	-4.6	-4.5	-5.0	68	301	9.3	9.3	12.4	0.0
2	3	3	-4.6	-4.3	-4.7	72	296	7.6	8.1	13.1	0.0
2	3	4	-4.8	-4.3	-4.9	67	220	2.2	8.1	12.1	0.0
2	3	5	-5.2	-4.7	-5.3	69	180	3.8	3.8	6.2	0.0
2	3	6	-5.7	-4.7	-5.8	71	187	4.7	4.7	6.8	0.0
2	3	7	-5.8	-5.7	-6.3	71	188	4.9	4.9	6.4	0.0
2	3	8	-5.8	-5.4	-5.9	69	184	4.5	5.2	6.6	0.0
2	3	9	-5.6	-5.6	-5.9	69	181	4.5	4.6	6.4	0.0
2	3	10	-5.7	-5.5	-6.0	73	182	3.5	5.0	6.6	0.0
2	3	11	-5.6	-5.1	-5.8	72	168	3.2	4.0	5.4	0.0
2	3	12	-4.9	-4.8	-5.6	65	165	2.5	3.3	4.5	0.0
2	3	13	-4.8	-4.1	-5.0	65	196	1.8	3.8	4.9	0.0
2	3	14	-4.1	-3.2	-4.9	68	228	3.5	3.5	4.6	0.0

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	°C	°C	%	degrees	m/s	m/s	m/s	mm
2	3	15	-2.9	-2.9	-4.1	62	157	0.7	3.1	3.9	0.0
2	3	16	-3.0	-2.8	-3.8	60	210	1.3	1.5	2.6	0.0
2	3	17	-5.7	-3.0	-6.6	77	224	0.6	1.9	3.0	0.0
2	3	18	-4.5	-4.1	-5.9	69	194	2.4	2.4	2.9	0.0
2	3	19	-3.7	-3.0	-4.5	72	190	1.5	2.7	3.8	0.0
2	3	20	-2.4	-2.2	-3.7	69	180	1.6	1.8	3.0	0.0
2	3	21	-1.2	-0.9	-2.6	67	223	2.0	2.2	3.0	0.0
2	3	22	-1.5	-1.2	-2.5	72	205	2.4	2.8	3.8	0.0
2	3	23	-1.1	-0.5	-3.1	72	166	2.2	3.5	3.9	0.0
2	3	24	0.5	1.1	-3.1	63	161	3.2	3.2	4.7	0.0
2	4	1	2.3	3.0	-0.6	61	194	3.2	3.2	5.2	0.0
2	4	2	2.2	3.1	0.4	60	180	3.6	4.1	5.8	0.0
2	4	3	3.7	4.8	1.0	52	202	5.2	5.7	7.9	0.0
2	4	4	4.0	4.7	1.7	60	213	7.4	7.4	11.5	0.0
2	4	5	5.1	5.6	4.0	58	193	6.7	8.2	12.7	0.0
2	4	6	3.0	6.2	3.0	71	196	5.3	6.2	9.8	0.0
2	4	7	4.3	4.5	3.0	64	256	11.3	11.3	15.8	0.0
2	4	8	2.2	4.3	1.7	61	248	9.7	10.5	12.8	0.0
2	4	9	2.8	3.1	-0.1	57	184	8.0	11.9	15.0	0.0
2	4	10	0.3	2.8	0.3	67	214	7.7	11.3	14.6	0.0
2	4	11	2.3	2.7	0.3	61	213	7.1	7.1	12.0	0.0
2	4	12	3.7	3.8	1.0	55	204	7.1	14.3	17.3	0.0
2	4	13	4.0	4.3	3.0	54	246	18.0	18.0	22.3	0.0
2	4	14	3.2	4.5	2.1	59	245	8.9	15.9	20.4	0.0
2	4	15	3.8	3.9	1.8	55	210	3.5	6.7	9.3	0.0
2	4	16	3.4	6.2	3.3	60	219	7.8	8.5	11.5	0.0
2	4	17	6.8	6.9	3.0	55	185	4.7	7.3	10.4	0.0
2	4	18	5.2	7.0	4.8	63	212	5.0	10.5	13.8	0.0
2	4	19	5.8	7.2	4.7	62	227	11.3	11.3	15.5	0.0
2	4	20	7.8	7.8	5.0	58	189	5.6	12.2	14.9	0.0
2	4	21	6.0	8.0	4.8	63	252	7.3	8.9	10.4	0.0
2	4	22	6.0	7.1	4.7	64	233	2.0	5.8	8.5	0.0
2	4	23	5.9	8.6	5.0	54	175	2.8	8.0	13.8	0.0
2	4	24	4.8	7.6	4.0	59	127	3.0	4.2	6.6	0.0
2	5	1	3.5	6.9	3.5	67	241	2.3	3.1	4.9	0.0
2	5	2	4.5	10.0	2.8	62	106	1.3	7.1	14.0	0.0
2	5	3	7.8	9.7	4.1	53	203	6.8	7.3	13.6	0.0
2	5	4	8.4	9.9	7.1	55	192	8.0	10.1	19.7	0.0
2	5	5	7.8	10.1	6.1	56	220	9.4	9.4	17.6	0.0
2	5	6	6.3	10.0	6.3	62	225	8.6	9.7	14.9	0.0

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	*°C*	*°C*	*%*	*degrees*	*m/s*	*m/s*	*m/s*	*mm*
2	5	7	7.1	8.7	5.8	60	154	1.4	8.0	12.7	0.0
2	5	8	5.1	8.6	5.1	66	213	8.1	8.1	12.9	0.0
2	5	9	6.7	7.4	3.7	60	216	2.6	6.1	13.4	0.0
2	5	10	6.8	8.5	5.8	55	194	1.9	4.5	10.0	0.0
2	5	11	6.0	8.8	4.3	60	252	8.3	8.3	10.7	0.0
2	5	12	4.8	6.1	4.2	64	159	2.8	7.0	8.3	0.0
2	5	13	4.4	6.7	3.8	62	209	1.8	3.0	4.1	0.0
2	5	14	6.4	6.7	3.5	50	133	2.2	2.8	4.3	0.0
2	5	15	5.1	7.3	5.1	57	132	1.9	5.2	7.6	0.0
2	5	16	4.8	8.1	4.6	58	218	3.4	5.0	7.7	0.0
2	5	17	4.8	7.0	4.4	59	160	2.1	3.6	5.0	0.0
2	5	18	4.1	6.6	3.1	65	158	2.2	4.2	5.8	0.0
2	5	19	3.7	4.8	2.6	68	210	2.9	4.0	5.1	0.0
2	5	20	2.4	3.9	2.2	73	210	2.5	3.7	4.6	0.0
2	5	21	2.9	3.0	1.6	72	149	2.2	2.6	3.5	0.0
2	5	22	1.7	2.9	1.5	77	335	0.5	1.9	2.9	0.0
2	5	23	4.3	4.4	1.4	60	141	1.8	2.8	3.8	0.0
2	5	24	6.7	7.7	4.3	50	241	7.5	10.5	12.9	0.0
2	6	1	8.4	8.4	5.9	49	219	8.8	10.2	13.8	0.0
2	6	2	7.2	8.7	5.3	53	206	2.2	7.0	10.7	0.0
2	6	3	6.1	8.1	5.2	59	183	5.3	5.8	9.9	0.0
2	6	4	5.4	6.9	3.5	67	182	6.2	6.9	9.3	0.0
2	6	5	4.6	6.6	4.4	71	180	4.8	8.2	13.4	0.0
2	6	6	5.0	5.7	4.2	72	224	3.9	7.0	9.4	0.0
2	6	7	4.9	5.9	3.5	73	187	5.4	7.8	10.4	0.0
2	6	8	4.2	5.3	3.6	72	196	5.9	5.9	9.3	0.0
2	6	9	5.1	5.4	3.9	71	206	7.6	7.6	13.0	0.0
2	6	10	5.0	6.7	4.2	70	188	7.2	9.8	14.6	0.0
2	6	11	5.0	6.1	4.5	74	177	6.5	7.7	10.8	0.0
2	6	12	5.8	6.6	4.4	67	217	8.4	8.4	12.7	0.0
2	6	13	6.3	6.9	5.1	67	195	9.5	9.9	14.9	0.0
2	6	14	4.6	6.4	4.1	63	240	14.7	14.9	22.7	0.0
2	6	15	3.9	4.8	3.4	62	179	3.9	11.6	17.8	0.0
2	6	16	2.6	3.9	2.4	65	257	5.3	7.6	11.6	0.0
2	6	17	0.8	2.8	0.5	63	219	7.9	7.9	11.6	0.0
2	6	18	0.0	1.4	-0.1	65	219	10.6	11.4	15.6	0.0
2	6	19	0.2	0.7	-0.1	65	239	14.1	14.1	19.3	0.0
2	6	20	0.4	0.5	-0.3	61	243	12.9	13.5	18.4	0.0
2	6	21	0.4	0.5	-0.4	53	259	16.4	16.4	22.9	0.0
2	6	22	0.3	0.5	-0.1	54	255	14.2	16.0	23.1	0.0

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	*°C*	*°C*	*%*	*degrees*	*m/s*	*m/s*	*m/s*	*mm*
2	6	23	-0.2	0.3	-0.8	60	235	9.5	11.2	16.5	0.0
2	6	24	-0.3	0.7	-0.4	70	235	11.4	13.0	18.3	0.0
2	7	1	1.1	1.4	-0.3	57	255	13.8	15.4	22.9	0.0
2	7	2	1.3	1.4	0.8	57	255	14.2	14.2	20.7	0.0
2	7	3	0.8	1.4	0.7	63	269	13.4	16.5	23.1	0.0
2	7	4	0.9	1.2	0.4	63	265	12.3	14.1	21.4	0.0
2	7	5	0.4	0.9	0.2	66	270	9.8	13.4	20.7	0.0
2	7	6	0.5	0.6	0.1	65	274	7.5	10.1	14.7	0.0
2	7	7	0.4	0.9	0.3	62	262	5.0	7.0	10.8	0.0
2	7	8	0.8	0.8	0.1	57	200	3.8	4.2	8.3	0.0
2	7	9	-0.6	0.8	-0.7	66	157	5.9	5.9	8.0	0.0
2	7	10	0.4	1.3	-0.7	61	151	5.7	6.1	8.9	0.0
2	7	11	2.4	2.4	0.1	55	157	8.2	8.2	11.1	0.0
2	7	12	3.0	3.6	2.3	51	174	5.0	6.7	12.1	0.0
2	7	13	3.0	3.1	2.3	53	150	6.6	6.6	10.1	0.0
2	7	14	3.0	4.1	2.9	52	195	3.5	6.4	9.0	0.0
2	7	15	1.9	3.0	1.9	62	149	3.3	6.2	8.2	0.0
2	7	16	2.3	3.2	1.5	60	182	3.2	5.4	7.1	0.0
2	7	17	2.5	3.6	2.0	62	183	4.9	5.7	8.8	0.0
2	7	18	1.4	2.5	1.3	66	167	3.8	4.8	6.0	0.0
2	7	19	3.9	4.4	1.4	55	112	3.2	4.4	6.3	0.0
2	7	20	4.2	6.6	3.7	54	174	3.8	4.6	7.6	0.0
2	7	21	3.9	5.1	3.4	64	187	4.3	5.1	7.3	0.0
2	7	22	9.7	9.8	3.6	55	201	7.4	7.4	14.6	0.0
2	7	23	8.0	10.1	7.2	60	190	4.3	9.5	15.2	0.0
2	7	24	6.1	8.0	5.8	66	192	6.9	6.9	9.2	0.0
2	8	1	8.1	8.3	5.8	60	157	5.2	8.3	12.6	0.0
2	8	2	9.9	10.1	6.8	56	198	10.7	10.7	20.1	0.0
2	8	3	9.3	10.3	6.1	56	179	8.8	12.4	19.5	0.0
2	8	4	6.1	10.0	5.5	65	214	8.8	11.6	17.2	0.0
2	8	5	7.2	8.8	6.1	62	174	8.1	10.9	15.5	0.0
2	8	6	7.9	8.0	6.1	59	158	9.9	9.9	16.0	0.0
2	8	7	8.0	8.9	7.5	58	174	9.6	11.6	16.9	0.0
2	8	8	8.8	9.1	7.4	54	172	12.1	13.1	20.7	0.0
2	8	9	8.4	10.1	7.8	56	179	7.9	10.8	16.5	0.0
2	8	10	10.1	10.5	7.3	46	187	11.6	13.1	22.2	0.0
2	8	11	7.5	10.7	7.2	55	194	11.4	11.4	19.7	0.0
2	8	12	9.5	10.5	6.3	52	183	10.6	11.3	21.3	0.0
2	8	13	8.5	10.0	7.8	53	163	8.0	10.3	16.0	0.0
2	8	14	8.7	9.4	7.3	49	176	10.5	10.5	16.8	0.0

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	*°C*	*°C*	*%*	*degrees*	*m/s*	*m/s*	*m/s*	*mm*
2	8	15	6.8	8.7	6.2	59	204	12.2	12.3	18.3	0.0
2	8	16	9.1	10.8	5.3	51	206	10.1	11.6	21.0	0.0
2	8	17	7.6	9.2	6.3	59	232	8.6	9.9	14.6	0.0
2	8	18	7.0	11.1	6.6	64	220	7.0	8.0	17.0	0.0
2	8	19	6.5	8.7	5.7	66	212	7.3	11.6	14.8	0.0
2	8	20	5.9	8.1	5.5	72	216	8.3	9.3	13.2	0.0
2	8	21	7.1	7.7	5.4	68	188	9.2	9.2	13.4	0.0
2	8	22	6.4	8.8	4.8	70	210	10.6	11.9	15.6	0.0
2	8	23	7.4	8.0	5.7	69	197	8.0	8.3	12.5	0.0
2	8	24	6.7	7.4	5.3	78	230	5.2	8.3	14.9	0.0
2	9	1	6.3	9.9	6.3	71	214	4.2	8.2	11.7	0.0
2	9	2	9.7	11.6	6.2	60	230	1.9	4.7	9.4	0.0
2	9	3	7.0	10.3	7.0	63	125	2.6	2.8	5.2	0.0
2	9	4	10.0	10.7	6.3	53	167	2.3	5.2	9.8	0.0
2	9	5	5.0	10.0	5.0	68	211	5.2	9.3	12.3	0.0
2	9	6	5.6	6.4	4.8	66	220	3.7	4.2	5.9	0.0
2	9	7	7.2	9.1	4.8	61	228	10.3	10.4	14.0	0.0
2	9	8	7.7	8.4	5.8	60	237	12.3	14.0	17.9	0.0
2	9	9	9.7	10.1	6.6	49	190	12.0	13.3	20.4	0.0
2	9	10	9.1	10.1	6.3	49	189	7.6	10.6	17.4	0.0
2	9	11	7.6	9.2	6.3	57	219	3.5	6.7	11.6	0.0
2	9	12	7.5	8.8	6.9	55	203	4.2	6.0	9.8	0.0
2	9	13	7.6	8.0	6.8	53	266	5.5	6.4	10.7	0.0
2	9	14	7.3	7.7	5.7	52	235	5.0	5.7	8.9	0.0
2	9	15	5.1	7.2	4.9	59	246	5.6	8.5	14.5	0.0
2	9	16	4.9	5.6	4.5	56	252	8.9	10.0	15.6	0.0
2	9	17	4.1	5.0	3.6	59	53	1.8	7.0	9.5	0.0
2	9	18	3.8	4.4	3.3	59	312	3.4	4.1	6.7	0.0
2	9	19	1.2	4.2	1.0	73	87	2.1	3.4	4.4	0.0
2	9	20	1.1	2.0	1.1	73	312	0.8	2.6	3.8	0.0
2	9	21	0.8	1.1	0.6	78	38	2.7	3.0	5.5	0.0
2	9	22	0.7	0.9	0.4	81	274	1.1	2.5	4.1	0.0
2	9	23	0.3	0.9	0.3	83	314	1.0	2.1	3.4	0.0
2	9	24	0.4	0.7	0.3	83	1	1.7	1.7	2.4	0.0
2	10	1	0.7	1.1	0.2	84	45	2.6	2.8	3.7	0.0
2	10	2	4.1	4.1	0.7	76	215	1.3	1.9	3.8	0.0
2	10	3	3.7	5.5	3.1	67	220	7.2	7.2	10.2	0.0
2	10	4	4.2	5.1	3.3	60	199	5.0	6.2	10.1	0.0
2	10	5	3.0	4.2	2.4	67	229	7.1	8.3	10.9	0.0
2	10	6	2.6	3.6	2.4	66	210	7.9	9.0	13.9	0.0

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	*°C*	*°C*	*%*	*degrees*	*m/s*	*m/s*	*m/s*	*mm*
2	10	7	2.1	3.0	1.5	65	214	7.4	9.7	14.1	0.0
2	10	8	1.4	2.3	0.7	60	221	6.1	8.8	12.4	0.0
2	10	9	0.6	1.9	0.6	55	237	11.4	13.3	21.0	0.0
2	10	10	-0.9	0.6	-1.0	65	227	7.8	12.7	16.7	0.0
2	10	11	-1.1	-0.5	-1.2	57	227	9.5	11.2	14.1	0.0
2	10	12	-0.9	-0.7	-1.7	57	236	7.0	8.8	12.2	0.0
2	10	13	-0.1	-0.1	-0.9	51	197	6.6	10.5	13.7	0.0
2	10	14	0.2	0.3	-0.5	48	197	7.1	10.8	15.6	0.0
2	10	15	-0.8	0.4	-1.0	58	208	5.5	9.9	14.7	0.0
2	10	16	-0.1	0.2	-0.8	53	195	5.8	5.8	9.2	0.0
2	10	17	-0.5	-0.1	-0.7	52	193	5.3	7.4	12.1	0.0
2	10	18	-0.7	0.0	-1.1	54	191	5.3	6.4	10.1	0.0
2	10	19	-0.8	-0.6	-1.3	56	192	6.0	6.7	11.0	0.0
2	10	20	-1.0	-0.4	-1.3	54	196	6.3	7.2	11.0	0.0
2	10	21	-1.2	-0.3	-1.9	57	200	4.6	9.1	12.9	0.0
2	10	22	-1.3	-0.1	-1.8	59	172	5.0	7.4	11.7	0.0
2	10	23	-1.3	-0.7	-2.0	58	223	9.8	9.8	12.9	0.0
2	10	24	-1.4	-1.1	-1.7	55	185	5.1	8.8	12.4	0.0
2	11	1	-2.1	-1.4	-2.2	51	186	7.8	8.0	11.5	0.0
2	11	2	-2.7	-2.1	-2.9	51	174	6.6	7.9	11.4	0.0
2	11	3	-2.4	-2.4	-3.0	43	174	10.3	10.3	16.7	0.0
2	11	4	-3.4	-2.2	-3.5	50	212	8.7	10.1	15.8	0.0
2	11	5	-3.8	-3.4	-4.3	54	231	9.1	10.1	13.1	0.0
2	11	6	-5.3	-3.7	-5.3	66	208	5.6	8.2	10.9	0.0
2	11	7	-5.2	-4.5	-5.5	64	226	6.7	7.3	8.9	0.0
2	11	8	-6.0	-5.1	-6.0	66	208	4.8	6.4	8.0	0.0
2	11	9	-5.3	-4.2	-6.3	63	244	4.7	5.6	8.4	0.0
2	11	10	-5.8	-5.1	-6.0	66	243	4.0	4.5	5.7	0.0
2	11	11	-6.1	-5.3	-6.2	69	179	3.1	5.0	6.1	0.0
2	11	12	-4.9	-4.9	-6.2	64	177	2.8	4.0	4.7	0.0
2	11	13	-3.8	-3.8	-4.9	64	215	2.6	5.2	6.9	0.0
2	11	14	-3.4	-3.4	-4.0	53	189	2.8	4.7	6.6	0.0
2	11	15	-4.5	-3.4	-4.5	62	208	3.4	4.3	5.8	0.0
2	11	16	-4.4	-4.3	-5.5	57	178	3.1	4.0	5.7	0.0
2	11	17	-4.2	-3.7	-5.0	62	182	3.9	3.9	6.2	0.0
2	11	18	-4.7	-3.9	-5.1	70	216	5.0	5.0	6.5	0.0
2	11	19	-5.0	-4.7	-5.4	62	196	4.0	4.1	6.3	0.0
2	11	20	-4.8	-4.2	-5.4	56	191	4.5	6.3	9.5	0.0
2	11	21	-6.5	-4.8	-6.7	62	174	4.2	5.1	7.2	0.0
2	11	22	-6.1	-6.1	-6.8	58	180	5.0	5.2	6.3	0.0

Egilsstaðir airport, station 4271 year 2015											
Month	**day**	**hr**	**temp**	**max**	**min**	**hum.**	**wind dir.**	**wind**	**max**	**max gust**	**perc.**
			°C	*°C*	*°C*	*%*	*degrees*	*m/s*	*m/s*	*m/s*	*mm*
2	11	23	-5.7	-5.5	-6.2	59	192	4.5	5.2	7.1	0.0
2	11	24	-6.0	-5.5	-6.0	60	195	5.0	5.8	9.1	0.0